INSTITUTION

OF

MECHANICAL ENGINEERS.

PROCEEDINGS.

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1865.

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1865.

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LIST OF MEMBERS,

WITH YEAR OF ELECTION.

1865.

MEMBERS.

1861. Abel, Charles Denton, 20 Southampton Buildings, London, W.C.
1848. Adams, William Alexander, Newbold Beeches, Leamington.
1859. Adamson, Daniel, Newton Moor Iron Works, Hyde, near Manchester.
1861. Addenbrooke, George, Rough Hay Furnaces, Darlaston, near Wednesbury.
1851. Addison, John, 6 Delahay Street, Westminster, S.W.
1858. Albaret, Auguste, Engine Works, Liancourt, Oise, France.
1847. Allan, Alexander, Worcester Engine Works, Worcester.
1865. Allen, William Daniel, Bessemer Steel Works, Sheffield.
1865. Alleyne, John Gay Newton, Butterley Iron Works, Alfreton.
1859. Alton, George, Midland Road, Derby.
1861. Amos, Charles Edwards, Grove Works, Southwark, London, S.E.
1856. Anderson, John, Superintendent of Machinery to the War Department, Royal Arsenal, Woolwich, S.E.
1856. Anderson, William, Erith Iron Works, Erith, Kent, S.E.
1862. Angus, Robert, Locomotive Superintendent, North Staffordshire Railway, Stoke-upon-Trent.
1858. Appleby, Charles Edward, Renishaw Iron Works, near Chesterfield.
1859. Armitage, William James, Farnley Iron Works, Leeds.
1863. Armstrong, John, Timber Works, 20 North Bridge Street, Sunderland.
1857. Armstrong, Joseph, Locomotive Superintendent, Great Western Railway, Swindon.
1858. Armstrong, Sir William George, Elswick, Newcastle-on-Tyne.
1857. Ashbury, James Lloyd, Openshaw Works, near Manchester.
1848. Ashbury, John, Openshaw Works, near Manchester.
1858. Atkinson, Charles, Fitzalan Steel Works, Sheffield.

1865. Bagshawe, John J., Thames Steel Works, Sheffield.
1865. Bailey, John, Blackhall Place Iron Works, Dublin.
1860. Bailey, Samuel, Mining Engineer, The Pleck, near Walsall.
1865. Baldwin, Martin, Bovereux Iron Works, Bilston.
1860. Barclay, John, Bowling Iron Works, near Bradford, Yorkshire.

1865. Barclay, William, Locomotive Superintendent, Inverness and Perth Railway, Inverness.
1860. Barker, Paul, Old Park Iron Works, Wednesbury.
1863. Barlow, Edward, Messrs. Dobson and Barlow, Machine Works, Bolton.
1862. Barrow, Joseph, Whalley Chambers, 88 King Street, Manchester.
1862. Barton, Edward, Carnforth Hæmatite Iron Works, Carnforth, near Lancaster.
1865. Bass, William, Solway Screw Bolt and Rivet Works, Workington.
1859. Bastow, Samuel, Cliff House Iron Works, West Hartlepool.
1860. Batho, William Fothergill, Messrs. Nettlefold and Chamberlain, Smethwick Screw Works, Birmingham.
1859. Beacock, Robert, Victoria Foundry, Leeds.
1860. Beale, William Phipson, 27 Victoria Street, Westminster, S.W.
1865. Beardshaw, Charles C., Baltic Steel Works, Sheffield.
1848. Beattie, Joseph, Locomotive Superintendent, London and South Western Railway, Nine Elms, London, S.
1859. Beck, Edward, Messrs. Neild and Co., Dallam Iron Works, Warrington.
1862. Beckett, Henry, Mining Engineer, Upper Penn, Wolverhampton.
1864. Beckton, James George, Whitby.
1865. Bell, Charles, North Staffordshire Railway, Locomotive Department, Stoke-upon-Trent.
1858. Bell, Isaac Lowthian, Clarence Felling and Wylam Iron Works, Newcastle-on-Tyne.
1865. Bell, John, Liver Foundry, Salford, Manchester.
1857. Bellhouse, Edward Taylor, Eagle Foundry, Hunt Street, Oxford Street, Manchester.
1865. Bennett, Henry, Wombridge Iron Works, near Wellington, Shropshire.
1854. Bennett, Peter Duckworth, Spon Lane Iron Foundry, Westbromwich.
1865. Benson, George Henry, Stocksbridge Works, Deepcar, near Sheffield.
1865. Benson, Martin, 14 Hinde Street, Manchester Square, London, W.
1861. Bessemer, Henry, 4 Queen Street Place, New Cannon Street, London, E.C.
1847. Beyer, Charles F., Messrs. Beyer Peacock and Co., Gorton Foundry, Manchester.
1861. Binns, Charles, Mining Engineer, Clay Cross, near Chesterfield.
1863. Birckel, John James, Regent's Canal Iron Works, Eagle Wharf Road, London, N.
1847. Birley, Henry, Haigh Foundry, near Wigan.
1856. Blackburn, Isaac, Witton Park Iron Works, Darlington.
1851. Blackwell, Samuel Holden, Dudley.
1865. Bladen, Charles, Jarrow Iron Works, near Gateshead.
1862. Blake, Henry Wollaston, Messrs. James Watt and Co., 18 London Street, London, E.C.
1862. Blyth, Alfred, Steam Engine Works, Fore Street, Limehouse, London, E.

1863. Boeddinghaus, Julius, Messrs. Heinrich Boeddinghaus and Sons, Elberfeld, Prussia.

1862. Bouch, Thomas, 78 George Street, Edinburgh.

1858. Bouch, William, Shildon Engine Works, Darlington.

1847. Bovill, George Hinton, 24 Duke Street, Westminster, S.W.

1858. Bower, John Wilkes, Lancashire and Yorkshire Railway, Engineer's Office, Manchester. (*Life Member.*)

1862. Boyd, Nelson, Belfast Foundry, Donegal Street, Belfast.

1854. Bragge, William, Atlas Steel and Iron Works, Sheffield.

1854. Bramwell, Frederick Joseph, 35A Great George Street, Westminster, S.W.

1861. Brierly, Henry, 27 Southampton Buildings, London, W.C.

1848. Broad, Robert, Horseley Iron Works, near Tipton.

1865. Brock, Walter, Vulcan Foundry, Glasgow.

1852. Brogden, Henry, Sale, near Manchester. (*Life Member.*)

1865. Brown, George, Rotherham Iron Works, Rotherham.

1863. Brown, Henry, Metropolitan Carriage and Wagon Company, Saltley Works, Birmingham.

1847. Brown, James, Jun., Messrs. James Watt and Co., Soho Foundry, near Birmingham.

1850. Brown, John, Atlas Steel and Iron Works, Sheffield.

1855. Brown, John, Mining Engineer, Barnsley.

1853. Brown, Ralph, Patent Shaft Works, Wednesbury.

1865. Bryant, Frederick William, Blackfriars Bridge Works, Chatham Place, London, E.C.

1858. Burn, Henry, Midland Railway, Locomotive Department, Derby.

1856. Butler, Ambrose Edmund, Kirkstall Forge, Leeds.

1863. Butler, Arthur, Surdah, Radshye, Lower Bengal, India.

1859. Butler, John, Old Foundry, Stanningley, near Leeds.

1859. Butler, John Octavius, Kirkstall Forge, Leeds.

1857. Cabry, Joseph, Resident Engineer, Blyth and Tyne Railway, Newcastle-on-Tyne.

1847. Cabry, Thomas, North Eastern Railway, York.

1847. Cammell, Charles, Cyclops Steel and Iron Works, Sheffield.

1864. Campbell, David, 20 Castle Street, Liverpool.

1864. Campbell, James, Staveley Coal and Iron Works, Staveley, near Chesterfield.

1860. Cannell, Fleetwood James, Old Park Iron Works, Wednesbury.

1860. Carbutt, Edward Hamer, Vulcan Iron Works, Thornton Road, Bradford, Yorkshire.

1865. Carlton, Samuel, Great Western Railway, Locomotive Department, Swindon.

1862. Carpmael, William, 24 Southampton Buildings, London, W.C.

1856. Carrett, William Elliott, Sun Foundry, Leeds.

1864. Carrington, William Thomas, 19 Great George Street, Westminster, S.W.
1858. Carson, James Irving, Locomotive Superintendent, West Hartlepool Harbour and Railway, Stockton-on-Tees.
1865. Cartwright, John, New Bond Street Iron Works, Coventry Road, Birmingham.
1857. Chrimes, Richard, Brass Works, Rotherham.
1854. Clark, Daniel Kinnear, 11 Adam Street, Adelphi, London, W.C.
1859. Clark, George, Monkwearmouth Engine Works, Sunderland.
1862. Clark, James, Knott Mill Iron Works, Manchester.
1865. Clarke, John, Railway Foundry, Jack Lane, Leeds.
1859. Clay, William, Mersey Steel and Iron Works, Sefton Street, Liverpool.
1863. Clayton, Robert, Soho Foundry, Preston.
1847. Clift, John Edward, Prospect Hill, Redditch.
1860. Clunes, Thomas, Worcester Engine Works, Worcester.
1865. Coates, Victor, Lagan Iron Works, Belfast.
1858. Cochrane, Charles, Woodside Iron Works, near Dudley.
1860. Cochrane, Henry, Ormesby Iron Works, Middlesbrough.
1854. Cochrane, John, Woodside Iron Works, near Dudley.
1864. Coddington, William, Ordnance Cotton Mill, Blackburn.
1847. Coke, Richard George, Mining Engineer, Chesterfield.
1864. Colburn, Zerah, 7 Gloucester Road, Regent's Park, London, N.W.
1853. Cooper, Samuel Thomas, Leeds Iron Works, Leeds.
1860. Cope, James, Mining Engineer, Pensnett, near Dudley.
1865. Corlett, Henry Lee, Great Southern and Western Railway, Carriage Department, Dublin.
1848. Corry, Edward, 8 New Broad Street, London, E.C.
1857. Cortazzi, Francis James, care of Hugh Hornby, Sandown, Wavertree, Liverpool.
1860. Coulthard, Hiram Craven, Park Iron Works, Blackburn.
1864. Cowans, John, St. Nicholas and Woodbank Iron Works, Carlisle.
1847. Cowper, Edward Alfred, 35A Great George Street, Westminster, S.W.
1862. Cox, Samuel H. F., 3 East Parade, Sheffield.
1863. Craig, Andrew, Rock Ferry, Birkenhead.
1847. Crampton, Thomas Russell, 12 Great George Street, Westminster, S.W.
1858. Crawhall, Joseph, St. Ann's Wire and Hemp Rope Works, Newcastle-on-Tyne.
1865. Cross, James, St. Helen's Locomotive Works, St. Helen's.
1863. Crow, George, Messrs. R. Stephenson and Co., South Street, Newcastle-on-Tyne.
1864. Crowe, Edward, Tees Side Iron Works, Middlesbrough.
1858. Cubitt, Charles, 3 Great George Street, Westminster, S.W.
1865. Curtis, Matthew, Phœnix Foundry, Chapel Street, Manchester.

1864. Daglish, George Heaton, St. Helen's Foundry, St. Helen's.
1865. Darby, Abraham, Ebbw Vale Iron Works, near Newport, Monmouthshire.
1864. Darby, Charles E., Brymbo Iron Works, near Wrexham.
1865. Davidson, James, Royal Arsenal, Laboratory Department, Woolwich, S.E.
1865. Davies, Benjamin, Huyton Bleach Works, near Chorley.
1863. Davy, Alfred, Park Iron Works, Sheffield.
1849. Dawes, George, Milton and Elsecar Iron Works, near Barnsley.
1860. Dawes, William Henry, Bromford Iron Works, Westbromwich.
1861. Dawson, Benjamin, South Hetton, near Fence Houses.
1862. Deakin, William, Monmer Lane Iron Works, Willenhall, near Wolverhampton.
1857. De Bergue, Charles, Strangeways Iron Works, Manchester.
1858. Dees, James, Whitehaven.
1858. Dempsey, William, 26 Great George Street, Westminster, S.W.
1864. Dewhurst, John, Wadsley Bridge Iron and Steel Works, near Sheffield.
1865. Dircks, Henry, 16 Bucklersbury, London, E.C. (*Life Member.*)
1859. Dixon, John, Railway Foundry, Bradford, Yorkshire.
1865. Dobson, Benjamin, Messrs. Dobson and Barlow, Machine Works, Bolton.
1865. Domville, Charles Kelloch, Resident Engineer and Locomotive Superintendent, Belfast and County Down Railway, Belfast.
1865. Douglas, Charles P., Consett Iron Works, near Gateshead.
1857. Douglas, George K., Messrs. R. Stephenson and Co., South Street, Newcastle-on-Tyne.
1857. Dove, George, St. Nicholas and Woodbank Iron Works, Carlisle.
1847. Dubs, Henry, Glasgow Locomotive Works, Glasgow.
1857. Dunlop, John Macmillan, Marlborough Street, Oxford Street, Manchester.
1854. Dunn, Thomas, Windsor Bridge Iron Works, Manchester.
1864. Dunn, Thomas Edward, Jumna Bridge, East Indian Railway, Allahabad, India: (or care of R. Dunn, Howick, near Alnwick).
1861. Dutton, Charles, Bromford Iron Works, Westbromwich.
1860. Dyson, George, Tudhoe Iron Works, near Ferryhill.
1865. Dyson, Robert, Phœnix Wheel Tyre and Axle Works, Rotherham.

1859. Eassie, Peter Boyd, Railway Saw Mills, Gloucester.
1858. Easton, Edward, Grove Works, Southwark, London, S.E.
1856. Eastwood, James, Railway Iron Works, Derby.
1862. Elder, John, Messrs. Randolph Elder and Co., Centre Street, Glasgow.
1859. Elliot, George, Houghton-le-Spring, near Fence Houses.
1865. Elliot, Walter, Civil Engineer to the Colonial Government, Gibraltar.
1860. Elwell, Thomas, Messrs. Varrall Elwell and Poulot, 9 Avenue Trudaine, Paris.
1853. England, George, Hatcham Iron Works, London, S.E.

1861. Esson, William, Engineer, Cheltenham Gas Works, Cheltenham.
1864. Etienne, Antonin, Engineer, Cordova and Seville Railway, Seville, Spain.
1857. Evans, John Campbell, Morden Iron Works, East Greenwich, S.E.
1848. Everitt, George Allen, Kingston Metal Works, Adderley Street, Birmingham.
1864. Everitt, William Edward, Kingston Metal Works, Adderley Street, Birmingham.
1865. Evers, Frank, Cradley Iron Works, near Stourbridge.

1857. Fairlie, Robert Francis, 56 Gracechurch Street, London, E.C.
1865. Faviell, Samuel Clough, Clarence Iron Works, Leeds.
1861. Fearnley, Thomas, Globe Works, Hall Lane, Bradford, Yorkshire.
1854. Fernie, John, Clarence Iron Works, Leeds.
1861. Field, Joshua, Cheltenham Place, Lambeth, London, S.
1865. Filliter, Edward, Resident Engineer, Leeds Water Works, 5 South Parade, Leeds.
1864. Fleet, Thomas, Crown Boiler Works, Westbromwich.
1861. Fleetwood, Daniel Joseph, Metal Rolling Mills, Icknield Port Road, Birmingham.
1847. Fletcher, Edward, Locomotive Superintendent, North Eastern Railway, Gateshead.
1858. Fletcher, Henry Allason, Lowca Engine Works, Whitehaven. (*Life Member.*)
1857. Fletcher, James, Messrs. W. Collier and Co., 2 Greengate, Salford, Manchester.
1859. Fogg, Robert, 17 Park Street, Westminster, S.W.
1861. Forster, Edward, Spon Lane Glass Works, near Birmingham.
1849. Forsyth, John C., North Staffordshire Railway, Stoke-upon-Trent.
1864. Foster, Edward Henry, Old Park Iron Works, Wednesbury.
1861. Foster, Sampson Lloyd, Old Park Iron Works, Wednesbury.
1847. Fothergill, Benjamin, 27 Cornhill, London, E.C.
1847. Fowler, John, 2 Queen Square Place, Westminster, S.W.
1847. Fox, Sir Charles, 8 New Street, Spring Gardens, London, S.W.
1864. Frankish, John, 1 Lord's Chambers, Corporation Street, Manchester.
1859. Fraser, John, 18 York Place, Leeds.
1856. Freeman, Joseph, 98 Cannon Street, London, E.C.
1864. Frost, Thomas, Canal Street Iron Works, Derby.
1852. Froude, William, Elmsleigh, Paignton, Torquay.

1865. Gainsford, William Dunn, Sheffield Coal Co., Sheffield.
1862. Galton, Capt. Douglas, R.E., War Office, Pall Mall, London, S.W.
1847. Garland, William S., Messrs. James Watt and Co., Soho Foundry, near Birmingham.

1848. Gibbons, Benjamin, Hill Hampton House, near Stourport.
1865. Gibbs, William, Deepfields Iron Works, near Wolverhampton.
1856. Gilkes, Edgar, Tees Engine Works, Middlesbrough.
1862. Godfrey, Samuel, Messrs. Bolckow and Vaughan's Iron Works, Middlesbrough.
1865. Göransson, Göran Fredrick, Steel Works, Gefle and Hägbo, Sweden.
1865. Gray, John McFarlane, Vauxhall Foundry, Liverpool.
1848. Green, Charles, Tube Works, Leek Street, Birmingham.
1861. Green, Edward, Jun., 3 Bank Street, Exchange, Manchester.
1858. Greenwood, Thomas, Albion Works, Armley Road, Leeds.
1857. Gregory, John, Engineer, Portuguese National Railway South of Tagus, Barriero, near Lisbon, Portugal.
1865. Greig, David, Steam Plough Works, Leeds.
1860. Grice, Frederic Groom, Stour Valley Works, Spon Lane, Westbromwich.
1865. Grimshaw, William Dakin, Harris Buildings, Icknield Port Road, Birmingham.

1861. Haden, William, Dixon's Green, Dudley.
1861. Haggie, Peter, Hemp and Wire Rope Works, Gateshead.
1864. Halkett, John Craigie, Cramond Iron Works, Edinburgh.
1863. Hall, Joseph, Gratz Iron Works, Gratz, Styria, Austria.
1857. Hall, William, Ashted Varnish and Colour Works, 167 Dartmouth Street, Birmingham.
1860. Hamilton, Gilbert, Messrs. James Watt and Co., Soho Foundry, near Birmingham.
1858. Harding, John, Beeston Manor Iron Works, Leeds.
1859. Harman, Henry William, Canal Street Works, Manchester.
1856. Harrison, George, Canada Works, Birkenhead.
1858. Harrison, Thomas Elliot, 1 Westminster Chambers, Victoria Street, Westminster, S.W.
1865. Harrison, William, Bank Foundry, Blackburn.
1865. Harrison, William Arthur, Cambridge Street Works, Manchester.
1863. Hartas, Isaac, Rosedale Iron Mines, near Pickering, Yorkshire.
1858. Haswell, John A., North Eastern Railway, Locomotive Department, Gateshead.
1857. Haughton, S. Wilfred, Greenbank, Carlow. (*Life Member.*)
1861. Hawkins, William Bailey, 24 Budge Row, Cannon Street, London, E.C.
1856. Hawksley, Thomas, 30 Great George Street, Westminster, S.W.
1848. Hawthorn, Robert, Forth Banks, Newcastle-on-Tyne.
1848. Hawthorn, William, Forth Banks, Newcastle-on-Tyne.
1862. Haynes, Thomas John, Calpe Foundry, North Front, Gibraltar.
1860. Head, John, Messrs. Ransomes and Sims, Orwell Works, Ipswich.

1858. Head, Thomas Howard, Teesdale Iron Works, Stockton-on-Tees.
1853. Headly, James Ind, Eagle Works, Cambridge.
1857. Healey, Edward Charles, 163 Strand, London, W.C.
1862. Heath, William J. W., Assistant Engineer, Ceylon Railway, Colombo, Ceylon: (or care of John J. Heath, 105 Vyse Street, Birmingham.)
1864. Heathfield, Richard, Lion Galvanising Works, Birmingham Heath, Birmingham.
1860. Heaton, George, Royal Copper Mint, Icknield Street East, Birmingham.
1865. Heptinstall, John, Rotherham Iron Works, Rotherham.
1865. Hetherington, John Muir, Vulcan Iron Works, Pollard Street, Manchester.
1864. Hetherington, William Isaac, Vulcan Works, Pollard Street, Manchester.
1864. Hide, Thomas C., 46 Fenchurch Street, London, E.C.
1863. Hind, Roger, Scotland Bank Iron Works, Warrington.
1862. Hingley, Samuel, Hart's Hill Iron Works, near Brierley Hill.
1858. Hodgson, Robert, North Eastern Railway, Newcastle-on-Tyne.
1852. Holcroft, James, Shut End, Brierley Hill.
1865. Holliday, John, Messrs. Bethell's Creosote Works, Westbromwich.
1863. Holt, Francis, Gorton Foundry, Manchester.
1848. Homersham, Samuel Collett, 19 Buckingham Street, Adelphi, London, W.C.
1860. Hopkins, James Innes, Tees Side Iron Works, Middlesbrough.
1856. Hopkinson, John, London Road Iron Works, Manchester.
1858. Hopper, George, Houghton-le-Spring Iron Works, near Fence Houses.
1858. Horsley, William, Jun., Whitehill Point Iron Works, Percy Main, near Newcastle-on-Tyne.
1851. Horton, Joshua, Ætna Works, Smethwick, near Birmingham.
1858. Hosking, John, Gateshead Iron Works, Gateshead.
1864. Howard, Eliot, 84 Upper Whitecross Street, London, E.C.
1860. Howard, James, Britannia Iron Works, Bedford.
1860. Howe, William, Clay Cross Coal and Iron Works, near Chesterfield.
1861. Howell, Joseph Bennett, Hartford Steel Works, Sheffield.
1862. Huber, Peter Emile, Iron Works, near Zurich, Switzerland.
1864. Hulse, William Wilson, Whalley Chambers, 88 King Street, Manchester.
1847. Humphrys, Edward, Deptford Pier, London, S.E.
1859. Hunt, James P., Gospel Oak Iron Works, Tipton.
1856. Hunt, Thomas, North of England Railway Carriage Works, West Strand, Preston.
1864. Hutchinson, Edward, Skerne Iron Works, Darlington.
1863. Hutton, Walter Stuart, Prospect Works, Hunslet Lane, Leeds.
1865. Hyde, Capt. Henry, R.E., Master of the Mint, Calcutta: (or care of Rev. H. M. C. Hyde, Camberwell, London, S.)

1857. Inshaw, John, Engine Works, Morville Street, Birmingham.

1865. Jackson, John, Harbour of Refuge Works, Alderney.
1859. Jackson, Matthew Murray, Messrs. Escher Wyss and Co., Engine Works, Zurich, Switzerland.
1847. Jackson, Peter Rothwell, Salford Rolling Mills, Manchester.
1861. Jackson, Robert, Ætna Steel Works, Sheffield.
1860. Jackson, Samuel, Cyclops Steel and Iron Works, Sheffield.
1858. Jaffrey, George William, Hartlepool Iron Works, Hartlepool.
1856. James, Jabez, 40 Prince's Street, Commercial Road, Lambeth, London, S.
1865. Jarvis, Edward George, Railway Saw Mills, Gloucester.
1855. Jeffcock, Parkin, Mining Engineer, Midland Road, Derby.
1861. Jeffcock, Thomas William, Mining Engineer, 18 Bank Street, Sheffield.
1863. Jeffreys, Edward A., Low Moor Iron Works, near Bradford, Yorkshire.
1857. Jenkins, William, Locomotive Superintendent, Lancashire and Yorkshire Railway, Miles Platting, Manchester.
1861. Jessop, Sydney, Park Steel Works, Sheffield.
1861. Jessop, Thomas, Park Steel Works, Sheffield.
1854. Jobson, John, Derwent Foundry, Derby.
1863. Johnson, Bryan, Flookersbrook Foundry, Chester.
1847. Johnson, James, North Staffordshire Railway, Engineer's Office, Stoke-upon-Trent.
1861. Johnson, Samuel Waite, Locomotive Superintendent, Great Eastern Railway, Stratford, London, E.
1861. Jones, Alfred, Ettingshall Iron Works, Bilston.
1861. Jones, David, Engineer, Rumney Railway, Machen, near Newport, Monmouthshire.
1847. Jones, Edward, Old Park Iron Works, Wednesbury.
1857. Jones, Hodgson, 26 Great George Street, Westminster, S.W.
1853. Joy, David, Cleveland Engine Works, Middlesbrough.

1857. Kay, James Clarkson, Phœnix Foundry, Bury, Lancashire.
1857. Kendall, William, Locomotive Superintendent, Blyth and Tyne Railway, Percy Main, near Newcastle-on-Tyne.
1863. Kennan, James, Agricultural Implement Works, 19 Fishamble Street, Dublin.
1847. Kennedy, James, Cressington Park, Aigburth, Liverpool.
1857. Kennedy, Lt.-Colonel John Pitt, Engineer, Bombay Baroda and Central Indian Railway; 10 Liverpool Street, New Broad Street, London, E.C.
1863. Kennedy, John Pitt, Bombay Baroda and Central Indian Railway; 10 Liverpool Street, New Broad Street, London, E.C.
1865. Kirkaldy, David, Testing and Experimental Works, The Grove, Southwark Street, London, S.E.
1848. Kirkham, John, 109 Euston Road, London, N.W.

B

1847. Kirtley, Matthew, Locomotive Superintendent, Midland Railway, Derby.
1864. Kirtley, William, Midland Railway, Locomotive Department, Derby.
1859. Kitson, Frederick William, Monkbridge Iron Works, Leeds.
1848. Kitson, James, Airedale Foundry, Leeds.
1859. Kitson, James, Jun., Monkbridge Iron Works, Leeds.
1863. Knight, Thomas, 130 Bradford Street, Birmingham.

1863. Lancaster, John, Kirkless Hall Coal and Iron Works, near Wigan.
1863. Latham, Ernest, 11 Park Grove, Bromley, Kent, S.E.
1860. Law, David, Phœnix Iron Works, Glasgow.
1857. Laybourn, John, Isca Foundry, Newport, Monmouthshire.
1856. Laybourn, Richard, Locomotive Superintendent, Monmouthshire Railway and Canal Company, Newport, Monmouthshire.
1860. Lea, Henry, 35 Paradise Street, Birmingham.
1865. Ledger, Joseph, West Cumberland Hæmatite Iron Works, Workington.
1862. Lee, J. C. Frank, 22 Great George Street, Westminster, S.W.
1863. Lees, Samuel, Jun., Park Bridge Iron Works, Ashton-under-Lyne.
1863. Leigh, Evan, Junction Works, Miles Platting, Manchester.
1865. Leigh, Frederick Allen, Junction Works, Miles Platting, Manchester.
1858. Leslie, Andrew, Iron Ship Building Yard, Hebburn Quay, Gateshead.
1856. Levick, Frederick, Cwm-Celyn Blaina and Coalbrook Vale Iron Works, near Newport, Monmouthshire.
1860. Lewis, Thomas William, Plymouth Iron Works, Merthyr Tydvil.
1864. Lindsley, George, Great Western Railway, Locomotive Department, Swindon.
1856. Linn, Alexander Grainger, 2 Queen Square Place, Westminster, S.W.
1857. Little, Charles, Staveley Coal and Iron Works, Staveley, near Chesterfield.
1863. Lloyd, Edward R., Albion Tube Works, Nile Street, Birmingham.
1854. Lloyd, George Braithwaite, Messrs. Lloyds, High Street, Birmingham. (*Life Member.*)
1862. Lloyd, John, Lilleshall Iron Works, Oakengates, near Wellington, Shropshire.
1847. Lloyd, Sampson, Old Park Iron Works, Wednesbury.
1864. Lloyd, Sampson Zachary, Old Park Iron Works, Wednesbury.
1852. Lloyd, Samuel, Old Park Iron Works, Wednesbury.
1862. Lloyd, Wilson, Old Park Iron Works, Wednesbury.
1863. Loam, Matthew Hill, Engineer, Gas and Water Works, Nottingham.
1856. Longridge, Robert Bewick, Steam Boiler Assurance Company, 67 King Street, Manchester.
1865. Longridge, William Smith, Alderwasley Iron Works, Ambergate, near Derby.
1859. Lord, Thomas Wilks, 2A Alfred Street, Boar Lane, Leeds.

1861. Low, George, St. Peter's Iron Works, Ipswich.
1865. Lundh, Sverier Hakon, 36 Regent Square, London, W.C.
1854. Lynde, James Gascoigne, Town Hall, Manchester.

1864. Macfarlane, Walter, Saracen Foundry, Glasgow.
1856. Mackay, John, Mount Hermon, Drogheda.
1864. Macnab, Archibald Francis, care of Charles Lee, 23 Allen Street, Hercules Buildings, Lambeth, London, S.
1865. MacNay, William, Shildon Engine Works, Darlington.
1865. Macnee, Daniel, Cyclops Steel and Iron Works, Sheffield.
1859. Manning, John, Boyne Engine Works, Hunslet, Leeds.
1862. Mansell, Richard Christopher, South Eastern Railway, Carriage Department, Ashford.
1862. Mappin, Frederick Thorpe, Sheaf Works, Sheffield.
1857. March, George, Union Foundry, Leeds.
1856. Markham, Charles, Staveley Coal and Iron Works, Staveley, near Chesterfield.
1865. Marshall, Francis Carr, Jarrow Engine Works, Quayside, Newcastle-on-Tyne.
1862. Marshall, James, 4 Gloucester Terrace, Rye Hill, Newcastle-on-Tyne.
1859. Marshall, William Ebenezer, Sun Foundry, Leeds.
1847. Marshall, William Prime, 81 Newhall Street, Birmingham.
1859. Marten, Edward Bindon, Engineer, Stourbridge Water Works, 13 High Street, Stourbridge.
1853. Marten, Henry, Parkfield Iron Works, near Wolverhampton.
1857. Martindale, Capt. Ben Hay, R.E., War Office, Pall Mall, London, S.W.
1854. Martineau, Francis Edgar, Globe Works, Cliveland Street, Birmingham.
1864. Martley, William, Locomotive Superintendent, London Chatham and Dover Railway, Longhedge Works, Wandsworth Road, London, S.
1857. Masselin, Armand, Folembray, Aisne, France.
1853. Mathews, William, The Leasowes, near Birmingham.
1848. Matthew, John, Messrs. John Penn and Co., Marine Engineers, Greenwich, S.E.
1847. Matthews, William Anthony, Sheaf Works, Sheffield.
1853. Maudslay, Henry, Cheltenham Place, Lambeth, London, S. (*Life Member.*)
1864. Maudslay, Thomas Henry, Cheltenham Place, Lambeth, London, S.
1861. May, Robert Charles, 3 Great George Street, Westminster, S.W.
1857. May, Walter, Suffolk Works, Berkley Street, Birmingham.
1865. Maylor, John, Engineer and Shipbuilder, Rio de Janeiro: Mayfield, King Street, Oxton, Birkenhead.
1859. Maylor, William, East Indian Iron Company, Beypoor, India: (or care of E. J. Burgess, Abchurch Chambers, Abchurch Yard, London, E.C.)

1847. McClean, John Robinson, 23 Great George Street, Westminster, S.W.
1865. McDonnell, Alexander, Locomotive Superintendent, Great Southern and Western Railway, Dublin.
1864. McEwen, Lawrence Thomson, Ormesby Iron Works, Middlesbrough.
1860. McKenzie, James, Well House Foundry, Leeds.
1859. McKenzie, John, Worcester Engine Works, Worcester.
1862. McPherson, Hugh, Engineer, Gloucester Gas Works, Gloucester.
1863. Meek, Sturges, Resident Engineer, Lancashire and Yorkshire Railway, Manchester.
1858. Meik, Thomas, Engineer to the River Wear Commissioners, Sunderland.
1857. Menelaus, William, Dowlais Iron Works, Merthyr Tydvil.
1857. Metford, William Ellis, Flook House, Taunton.
1847. Middleton, William, Vulcan Iron Foundry, Summer Lane, Birmingham.
1862. Miers, Francis C., Stoneleigh Lodge, Grove Road, Clapham Park, London, S.
1864. Miers, John William, 74 Addison Road, Kensington, London, W.
1862. Millward, John, 27 Paradise Street, Birmingham.
1856. Mitchell, Charles, Iron Ship Building Yard, Low Walker, Newcastle-on-Tyne.
1858. Mitchell, James, 3 Church Terrace, Higher Tranmere, Birkenhead.
1861. Mitchell, Joseph, Worsbrough Dale Colliery, near Barnsley.
1859. Moor, William, Engineer, Hetton Colliery, Hetton, near Fence Houses.
1864. Moore, Sampson, North Foundry, Cotton Street, Clarence Dock, Liverpool.
1864. Morgan, Joshua Llewelyn, Kingscombe, near Cowbridge.
1849. Morrison, Robert, Ouseburn Engine Works, Newcastle-on-Tyne.
1865. Morton, Robert, Brass Works, Stockton-on-Tees.
1865. Mosse, James Robert, Mauritius Railways, Port Louis, Mauritius.
1858. Mountain, Charles George, Suffolk Works, Berkley Street, Birmingham.
1863. Muir, William, Britannia Works, Sherborne Street, Strangeways, Manchester.
1857. Muntz, George Frederick, French Walls, near Birmingham.
1865. Murdock, William Mallabey, Eagle Foundry, Northampton.
1859. Murphy, James, Railway Works, Newport, Monmouthshire.
1858. Murray, Thomas H., Engine Works, Chester-le-Street, near Fence Houses.
1863. Musgrave, John, Jun., Globe Iron Works, Bolton.

1848. Napier, John, Vulcan Foundry, Glasgow.
1856. Napier, Robert, West Shandon, Helensburgh, near Glasgow. (*Life Member.*)
1861. Naylor, John William, Wellington Foundry, Leeds.
1858. Naylor, William, Great Indian Peninsula Railway, 3 New Broad Street, London, E.C.
1863. Neilson, Walter Montgomerie, Hyde Park Locomotive Works, Glasgow.

1860. Nettlefold, Joseph Henry, Screw Works, Broad Street, Birmingham.
1856. Newall, James, East Lancashire Railway, Carriage Department, Bury, Lancashire.
1862. Newton, William Edward, 66 Chancery Lane, London, W.C.
1858. Nichol, Peter Dale, Locomotive Superintendent, East Indian Railway, Allahabad, India: (or care of Anthony Nichol, 19 Quay, Newcastle-on-Tyne.)
1850. Norris, Richard Stuart, 272 Upper Parliament Street, Liverpool.

1864. Ommanney, Frederick Francis, New Bridge Foundry, Adelphi Street, Salford, Manchester.
1847. Owen, William, Phœnix Wheel Tyre and Axle Works, Rotherham.

1859. Paquin, Jean François, Locomotive Superintendent, Madrid Saragossa and Alicante Railways, Madrid, Spain.
1865. Parkes, Alexander, Stephenson Metal Tube Works, Liverpool Street, Birmingham.
1860. Parkin, John, Harvest Lane Steel Works, Sheffield.
1847. Peacock, Richard, Messrs. Beyer Peacock and Co., Gorton Foundry, Manchester.
1848. Pearson, John, 7 Old Hall Street, Liverpool.
1859. Peet, Henry, London and North Western Railway, Locomotive Department, Wolverton.
1848. Penn, John, The Cedars, Lee, Kent, S.E. (*Life Member.*)
1861. Perkins, Loftus, 6 Francis Street, Regent Square, London, W.C.
1856. Perring, John Shae, 104 King Street, Manchester.
1863. Perry, Thomas J., Highfields Engine Works, Bilston.
1865. Perry, William, Messrs. Samuel Perry and Sons, Wednesbury.
1860. Peyton, Edward, Bordesley Works, Birmingham.
1856. Piggott, George, Birmingham Heath Boiler Works, Birmingham.
1854. Pilkington, Richard, Jun., 45 Leamington Road Villas, Bayswater, London, W.
1859. Pitts, Joseph, Old Foundry, Stanningley, near Leeds.
1859. Platt, John, Hartford Iron Works, Oldham.
1862. Player, John, Norton, near Stockton-on-Tees.
1861. Plum, Thomas William, Ravensdale Iron Works, Tunstall, near Stoke-upon-Trent.
1856. Pollard, John, Midland Junction Foundry, Leeds.
1860. Ponsonby, Edward Vincent, Engineer, Great Western Railway, Worcester.
1852. Porter, John Henderson, Ebro Works, Tividale, near Tipton.
1861. Porter, Robert, Ebro Works, Tividale, near Tipton.
1864. Potts, Benjamin Langford Foster, 150 Camberwell Grove, London, S.

1851. Potts, John Thorpe, 3 East Parade, Sheffield.
1865. Pratchitt, William, Denton Iron Works, Carlisle.
1856. Preston, Francis, Ancoats Bridge Works, Ardwick, Manchester.

1862. Rake, Alfred Stansfield, East Howden, near Newcastle-on-Tyne.
1864. Ramage, Robert, Locomotive Superintendent, Midland Great Western Railway, Dublin.
1847. Ramsbottom, John, Locomotive Superintendent, London and North Western Railway, Crewe.
1860. Ransome, Allen, Jun., Messrs. Worssam and Co., King's Road, Chelsea, London, S.W.
1862. Ransome, Robert James, Orwell Works, Ipswich.
1862. Ravenhill, John R., Glass House Fields, Ratcliff, London, E.
1859. Rennie, George Banks, 39 Wilton Crescent, Belgrave Square, London, S.W.
1862. Reynolds, Edward, Don Steel Works, Sheffield.
1863. Richards, Edwin, Nantyglo Iron Works, near Newport, Monmouthshire.
1865. Richards, Job, Rabone Bridge Iron Works, Smethwick, near Birmingham.
1856. Richards, Josiah, Abersychan Iron Works, Pontypool.
1863. Richardson, Edward, Engineer, Lyttelton, New Zealand.
1865. Richardson, John, Engineer to the Corporation and the Water Works, Gloucester.
1858. Richardson, Thomas, Hartlepool Iron Works, Hartlepool.
1859. Richardson, William, Hartford Iron Works, Oldham.
1865. Rideal, Samuel, 18 Hopwood Avenue, Manchester.
1863. Rigby, Samuel, Cock Hedge Mill, Warrington.
1848. Robertson, Henry, Great Western Railway, Shrewsbury.
1865. Robey, Robert, Perseverance Iron Works, Lincoln.
1859. Robinson, John, Messrs. Sharp Stewart and Co., Atlas Works, Manchester.
1865. Robinson, John, Railway Works, Rochdale.
1853. Ronayne, Joseph P., 4 Harbour Hill, Queenstown.
1856. Rouse, Frederick, Great Northern Railway, Locomotive Department, Boston.
1857. Routledge, William, New Bridge Foundry, Adelphi Street, Salford, Manchester
1860. Rumble, Thomas William, 5 Westminster Chambers, Victoria Street, Westminster, S.W.
1847. Russell, John Scott, 20 Great George Street, Westminster, S.W.
1863. Ryder, William, Bark Street, Bolton.

1859. Sacré, Charles, Locomotive Superintendent, Manchester Sheffield and Lincolnshire Railway, Gorton, near Manchester.
1864. Said, Colonel M., Bey, Engineer, Turkish Service, Constantinople: (or care of J. C. Frank Lee, 22 Great George Street, Westminster, S.W.)

1859. Salt, George, Saltaire, near Bradford, Yorkshire.
1864. Samuda, Joseph D'Aguilar, M.P., Iron Ship Building Yard, Isle of Dogs, Poplar, London, E.
1848. Samuel, James, 26 Great George Street, Westminster, S.W.
1857. Samuelson, Alexander, 27 Cornhill, London, E.C.
1865. Samuelson, Bernhard, M.P., Britannia Iron Works, Banbury.
1857. Samuelson, Martin, Scott Street Foundry, Hull.
1865. Sandberg, Christer Peter, Engineer, Swedish Government Railway Service, Stockholm, Sweden: (or care of Messrs. Tottie and Sons, 2 Alderman's Walk, Bishopsgate Street, London, E.C.)
1861. Sanderson, George Grant, Parkgate Iron Works, Rotherham.
1864. Sanderson, John, Locomotive Superintendent, Whitehaven Cleator and Egremont Railway, Moor Row, near Whitehaven.
1860. Schneider, Henry William, M.P., Ulverstone Hæmatite Iron Works, Barrow, near Ulverstone.
1865. Scott, Edward, 10 Tib Lane, Cross Street, Manchester.
1861. Scott, Walter Henry, Locomotive and Carriage Superintendent, Mauritius Railways, Port Louis, Mauritius: (or care of Joseph Reid, 49 Arundel Square, London, N.)
1864. Seddon, John, 31 King Street, Wigan.
1857. Selby, George Thomas, Smethwick Tube Works, Birmingham.
1865. Sellers, William, Pennsylvania Avenue, Philadelphia, United States.
1850. Shanks, Andrew, 6 Robert Street, Adelphi, London, W.C.
1863. Sharp, Henry, Bolton Iron and Steel Works, Bolton.
1862. Sharpe, William John, 1 Victoria Street, Westminster, S.W.
1864. Shaw, Duncan, Mining Engineer, Cordova, Spain.
1856. Shelley, Charles Percy Bysshe, 21 Parliament Street, Westminster, S.W.
1861. Shepherd, John, Union Foundry, Hunslet Road, Leeds.
1859. Shuttleworth, Joseph, Stamp End Iron Works, Lincoln.
1851. Siemens, Charles William, 3 Great George Street, Westminster, S.W.
1862. Silvester, John, Messrs. George Salter and Co., Spring Balance Works, Westbromwich.
1847. Sinclair, Robert, Great Eastern Railway, Stratford, London, E.
1857. Sinclair, Robert Cooper, 13 Bennett's Hill, Birmingham.
1859. Slater, Isaac, Gloucester Wagon Works, Gloucester.
1853. Slaughter, Edward, Avonside Engine Works, Bristol.
1854. Smith, George, Wellington Road, Dudley.
1860. Smith, Henry, Brierley Hill Iron Works, Brierley Hill.
1858. Smith, Isaac, 36 Lancaster Street, Birmingham.
1860. Smith, John, Brass Foundry, Traffic Street, Derby.
1857. Smith, Josiah Timmis, Ulverstone Hæmatite Iron Works, Barrow, near Ulverstone.

1859. Smith, Matthew, Caledonia Wire Mills, Halifax.
1860. Smith, Richard, Berry Hill, Lichfield.
1857. Smith, William, 19 Salisbury Street, Adelphi, London, W.C.
1863. Smith, William Ford, Gresley Iron Works, Ordsal Lane, Salford, Manchester.
1857. Snowdon, Thomas, 147 High Street, Stockton-on-Tees.
1859. Sokoloff, Capt. Alexander, Engineer, Russian Imperial Service, Steam Marine Department, Cronstadt, Russia: (or care of Messrs. W. Collier and Co., 2 Greengate, Salford, Manchester.)
1863. Somerville, Wallace Cochrane, London Works, Birmingham.
1858. Sörensen, Bergerius, Engineer-in-Chief, Royal Norwegian Navy Department, Horten Dockyard, Norway: (or care of Messrs. Tottie and Sons, 2 Alderman's Walk, Bishopsgate Street, London, E.C.)
1865. Sparrow, Arthur, Lane End Iron Works, Longton, near Stoke-upon-Trent.
1865. Sparrow, William Mander, Osier Bed Iron Works, Wolverhampton.
1859. Spencer, John Frederick, 3 St. Nicholas Buildings, Newcastle-on-Tyne.
1853. Spencer, Thomas, Old Park Works, near Shiffnal.
1854. Spencer, Thomas, Newburn Steel Works, Newcastle-on-Tyne.
1864. Spittle, Thomas, Cambrian Iron Foundry, Newport, Monmouthshire.
1862. Stableford, William, Oldbury Carriage Works, near Birmingham.
1859. Stewart, Charles P., Messrs. Sharp Stewart and Co., Atlas Works, Manchester.
1851. Stewart, John, Blackwall Iron Works, Russell Street, Blackwall, London, E.
1864. Stokes, James Folliott, Meole Brace, Shrewsbury.
1863. Storey, John Henry, Knott Mill Brass and Copper Works, Little Peter Street, Manchester.
1862. Strong, Joseph F., Resident Engineer, East Indian Railway, Cawnpore, India.
1865. Stroudley, William, Locomotive Superintendent, Highland Railway, Inverness.
1861. Sumner, William, 21 Clarence Street, Manchester.
1860. Swindell, James Evers, Parkhead Iron Works, Dudley.
1864. Swindell, James Swindell Evers, Cradley Iron Works, near Brierley Hill.
1859. Swingler, Thomas, Victoria Foundry, Litchurch, near Derby.

1861. Tangye, James, Cornwall Works, Clement Street, Birmingham.
1859. Tannett, Thomas, Victoria Foundry, Leeds.
1861. Taylor, George, Clarence Iron Works, Leeds.
1858. Taylor, James, Britannia Engine Works, Cleveland Street, Birkenhead.
1862. Taylor, John, Mining Engineer, 6 Queen Street Place, Upper Thames Street, London, E.C.

1862. Taylor, Richard, Mining Engineer, 6 Queen Street Place, Upper Thames Street, London, E.C.

1864. Tennant, Charles, The Glen, Innerleithen, near Edinburgh. (*Life Member.*)

1864. Thomas, Thomas, Clyde House, Canton, Cardiff.

1857. Thompson, Robert, Haigh Foundry, near Wigan.

1862. Thompson, William, Spring Gardens Engine Works, Newcastle-on-Tyne.

1852. Thomson, George, Crookhay Iron Works, Westbromwich.

1865. Thorn, Alexander, Steam Saw Mills, Chelsea, London, S.W.

1861. Thwaites, Robinson, Vulcan Iron Works, Thornton Road, Bradford, Yorkshire.

1865. Tickle, John, Providence Engine Works, Westbromwich.

1862. Tijou, William, 9 Great George Street, Westminster, S.W.

1861. Tipping, Isaac, H. M. Gun Carriage Manufactory, Madras, India: (or care of H. Tipping, Bridgewater Foundry, Patricroft, near Manchester.)

1862. Tolmé, Julian Horn, 1 Victoria Street, Westminster, S.W.

1863. Tomlinson, Edward, Miles Platting Works, Elm Street, Manchester.

1857. Tomlinson, Joseph, Jun., Locomotive Superintendent, Taff Vale Railway, Cardiff.

1865. Toomey, Edward, Royal Phœnix Iron Works, Dublin.

1856. Tosh, George, Locomotive Superintendent, Maryport and Carlisle Railway, Maryport.

1860. Townsend, Thomas C., 16 Talbot Chambers, Shrewsbury.

1863. Townsend, William, West Orchard, Coventry.

1865. Trow, John James, Messrs. William Trow and Sons, Wednesbury.

1862. Troward, Charles, Great Northern Railway, Locomotive Department, Doncaster.

1859. Turner, Edwin, Bowling Iron Works, near Bradford, Yorkshire.

1856. Tyler, Capt. Henry Wheetley, R.E., Railway Department, Board of Trade, Whitehall, London, S.W.

1862. Upward, Alfred, Engineer, Chartered Gas Works, 146 Goswell Street, London, E.C.

1865. Usher, George Moon, Beverley Iron Works, Beverley.

1862. Vavasseur, Josiah, Bear Lane, Southwark Street, London, S.E.

1856. Vernon, John, Iron Ship Building Yard, Brunswick Dock, Liverpool.

1865. Vickers, Albert, Don Steel Works, Sheffield.

1861. Vickers, Thomas Edward, Don Steel Works, Sheffield.

1856. Waddington, John, New Dock Iron Works, Leeds.

1856. Waddington, Thomas, New Dock Iron Works, Leeds.

1865. Wainwright, William, Great Western Railway, Locomotive Department, Worcester.

1863. Wakefield, John, Locomotive Superintendent, Dublin Wicklow and Wexford Railway, Dublin.

1864. Walker, Bernard Peard, Junction Cut Nail Works, Wolverhampton.

1861. Walker, John G., Netherton Iron Works, near Dudley.

1847. Walker, Thomas, Patent Shaft Works, Wednesbury.

1863. Walker, William Hugill, Wicker Iron Works, Sheffield.

1863. Wallace, William, Superintending Engineer, Montreal Ocean Steam Ship Company, Liverpool.

1865. Waller, George Arthur, Messrs. Guinness, James' Gate, Dublin.

1865. Walpole, Thomas, Port of Dublin Ship Yard, Dublin.

1864. Warden, Walter Evers, Phœnix Bolt and Nut Works, Glover Street, Birmingham.

1856. Wardle, Charles Wetherell, Boyne Engine Works, Hunslet, Leeds.

1852. Warham, John R., Burton Iron Works, Burton-on-Trent.

1862. Watkins, Richard, Canal Iron Works, Poplar, London, E.

1862. Webb, Francis William, London and North Western Railway, Locomotive Department, Crewe.

1862. Webb, Henry Arthur, Bretwell Hall Iron Works, near Stourbridge.

1860. Weild, William, Queen's Chambers, Market Street, Manchester.

1862. Wells, Charles, Moxley Iron Works, near Bilston.

1862. Westmacott, Percy G. B., Elswick Engine Works, Newcastle-on-Tyne.

1856. Wheeldon, Frederick R., Highfields Engine Works, Bilston.

1864. White, Isaiah, Messrs. Portilla and White, Engineers and Iron Ship Builders, Seville, Spain: (or care of Isaac White, Pontardulais, Llanelly.)

1859. Whitham, James, Perseverance Iron Works, Kirkstall Road, Leeds.

1859. Whitham, Joseph, Perseverance Iron Works, Kirkstall Road, Leeds.

1863. Whitley, Joseph, New British Iron Works, Corngreaves, near Birmingham.

1847. Whitworth, Joseph, Chorlton Street, Manchester.

1852. Whytehead, William Keld, Engineer-in-Chief to the Government of Paraguay: 32 Cambridge Street, Eccleston Square, London, S.W.

1859. Wickham, Henry Wickham, M.P., Low Moor Iron Works, near Bradford Yorkshire.

1859. Wickham, Lamplugh Wickham, Low Moor Iron Works, near Bradford, Yorkshire.

1863. Wicksteed, Thomas, 8 Torquay Terrace, Headingley, near Leeds. (*Life Member.*)

1865. Williams, Edward, Messrs. Bolckow and Vaughan's Iron Works, Middlesbrough.

1847. Williams, Richard, Patent Shaft Works, Wednesbury.

1859. Williams, Richard Price, Stocksbridge Works, Deepcar, near Sheffield.
1856. Wilson, Edward, Great Western Railway, Worcester.
1859. Wilson, George, Cyclops Steel and Iron Works, Sheffield.
1865. Wilson, James Edwards, Engineer, Indian Branch Railways; 1 Westminster Buildings, Westminster, S.W.
1863. Wilson, John Charles, East India House, 5 Lime Street, London, E.C.
1852. Wilson, Joseph W., 9 Buckingham Street, Strand, London, W.C.
1857. Wilson, Robert, Bridgewater Foundry, Patricroft, near Manchester.
1860. Wilson, William, 4 Victoria Street, Westminster, S.W.
1865. Winby, Clifford Etches, Atlas Iron Works, Cardiff.
1862. Winby, William Edward, Old Park Iron Works, Wednesbury.
1859. Winter, Thomas Bradbury, 28 Moorgate Street, London, E.C.
1863. Wise, Francis, Chandos Chambers, Buckingham Street, Adelphi, London, W.C.
1858. Wood, Nicholas, Hetton Hall, Hetton, near Fence Houses.
1865. Woodall, Solomon, Windmill End Boiler Works, near Dudley.
1848. Woodhouse, Henry, London and North Western Railway, Stafford.
1851. Woodhouse, John Thomas, Mining Engineer, Midland Road, Derby.
1858. Woods, Hamilton, Messrs. Allsopp and Sons, Burton-on-Trent.
1860. Worthington, Samuel Barton, Engineer, London and North Western Railway, Manchester.
1859. Wright, Joseph, Metropolitan Carriage and Wagon Company, Saltley Works, Birmingham.
1860. Wright, Joseph, Neptune Forge, Tipton Green, Dudley.
1863. Wright, Owen, Broadwell Forge, Oldbury, near Birmingham.
1863. Wright, Peter, Railway Wheel Vice and Anchor Works, Dudley.
1865. Wyllie, Andrew, Vauxhall Foundry, Liverpool.
1853. Wymer, Francis W., Superintending Engineer, Tyne Steam Shipping Company, Quayside, Newcastle-on-Tyne.

1861. Yule, William, Nevesky Foundry, St. Petersburg, Russia.

HONORARY LIFE MEMBERS.

1865. Downing, Samuel, LL.D., Museum Building, Trinity College, Dublin.
1847. Fairbairn, William, LL.D., The Polygon, Ardwick, Manchester.

HONORARY MEMBERS.

1865. Barker, Frederick, Leeds Iron Works, Leeds.
1848. Branson, George, Belmont Row, Birmingham.
1864. Branson, Joseph W., Belmont Row, Birmingham.
1863. Brockbank, William, 37 Princess Street, Manchester.

1863. Butler, William, 15 Bilbao Street, Cadiz, Spain.
1851. Clare, Thomas Deykin, Carr's Lane, Birmingham.
1848. Crosby, Samuel, Leek Street, Birmingham.
1863. Fairbairn, John, Farnley Iron Works, Leeds.
1863. Fisher, John, Priory Street, Dudley.
1863. Forster, George Emmerson, Collingwood Chambers, Newcastle-on-Tyne.
1865. Gössell, Otto, 22 Moorgate Street, London, E.C.
1863. Hackney, William, 3 Great George Street, Westminster, S.W.
1865. Hall, John, Lancashire Steel Co., Gorton Lane, Manchester.
1864. Hornblower, Joseph Wells, 14 Waterloo Street, Birmingham.
1860. Hutchinson, William, Blue Lias Lime Stone Offices, Lyme Regis.
1858. Lawton, Benjamin C., Benwell Grange, Newcastle-on-Tyne.
1859. Leather, John Towlerton, Leventhorpe Hall, near Leeds. (*Life Member.*)
1865. Longsdon, Alfred, 11 New Broad Street, London, E.C.
1860. Manby, Cordy, Tower Street, Dudley.
1863. Nichols, William, Midland Copper Works, Guild Street, Burton-on-Trent.
1865. Parry, David, Leeds Iron Works, Leeds.
1864. Parsons, Charles T., Ann Street, Birmingham.
1856. Pettifor, Joseph, Midland Railway, Derby.
1864. Peyton, Abel, Oakhurst, Church Road, Edgbaston, Birmingham.
1861. Ratcliff, Charles, Wyddrington, Edgbaston, Birmingham.
1863. Rigg, Arthur, The College, Chester.
1859. Sherriff, Alexander Clunes, Great Western Railway, Worcester.
1863. Storey, Thomas R., 17 Gracechurch Street, London, E.C.
1864. Tennant, John, St. Rollox Chemical Works, Glasgow. (*Life Member.*)
1864. Thornton, Falkland Samuel, Bradford Street, Birmingham.
1865. Warden, Thomas, Lionel Street, Birmingham.
1848. Warden, William Marston, Edgbaston Street, Birmingham.
1858. Waterhouse, Thomas, Claremont Place, Sheffield.
1862. Whitehead, William, Don Steel Works, Sheffield.
1865. Whitley, Joseph, Bowman Lane, Leeds.
1863. Woolley, John, Marehay Colliery, Ripley, near Derby.

GRADUATES.

1850. Glydon, George, Spring Hill Tube and Metal Works, Eyre Street, Birmingham.
1865. Hewett, Edward Edwards, Midland Railway, Locomotive Department, Derby.
1861. Middleton, Henry Charles, Vulcan Iron Foundry, Summer Lane, Birmingham.

PROCEEDINGS.

26 January, 1865.

The Eighteenth Anniversary Meeting of the Members was held in the Lecture Theatre of the Midland Institute, Birmingham, on Thursday, 26th January, 1865; Robert Napier, Esq., President, in the Chair.

The Minutes of the last General Meeting were read and confirmed.

The Secretary then read the following

ANNUAL REPORT OF THE COUNCIL.

1865.

The Council have great pleasure, on this the Eighteenth Anniversary of the Institution, in congratulating the Members on the very satisfactory position and the continued progress of the Institution.

The Financial statement of the affairs of the Institution for the year ending 31st December 1864 shows a balance in the Treasurer's hands of £2901 19*s.* 5*d.* after the payment of the accounts due to that date. The Finance Committee have examined and checked the receipts and payments of the Institution for the last year 1864, and report that the following Balance Sheet rendered by the Treasurer is correct. (*See Balance Sheet appended.*)

The Council report with great satisfaction the continued increase in the number of Members that has taken place during the last year; the total number of Members of all classes for the year being 572, of whom 12 are Life Members, 29 are Honorary Members, and 2 are Graduates, being an effective increase of 32 during the year.

The following deceases of Members of the Institution have occurred during the last year 1864:—

James Allen,	Manchester.
William Harrison Barwell,	Northampton.
William Steel Brown,	Glasgow.
John Fowler,	Leeds.
John Hedley,	Newcastle-on-Tyne.
Edwin Marshall,	Birmingham.
George Mackey Miller,	Dublin.
William Simpson,	London.
Charles Lingard Stokes,	London.
William Henry Woodhouse,	London.

The Council have the pleasure of acknowledging the following Donations to the Library of the Institution during the past year; and also of expressing their thanks to the Donors for the valuable and acceptable additions they have presented. The Council wish to urge on the attention of the Members the important advantage of obtaining a good collection of Engineering Books, Drawings, and Models in the Institution, for the purpose of reference by the Members personally or by correspondence; and they trust this desirable object will be promoted by the Members generally, so that by their united aid it may be efficiently accomplished. Members are requested to present copies of their Works to the Library of the Institution.

LIST OF DONATIONS TO THE LIBRARY.

Treatise on Practical Hydraulics, by Samuel Downing; from the author.

Description of Haarlem Lake Drainage, by Samuel Downing; from the author.

The Exhibited Machinery of 1862, by D. K. Clark; from the President.

On the Combustion of Coal, by C. Wye Williams; from Mr. Zerah Colburn.

Papers on Iron, and on the effect of Impact upon Wrought Iron Girders, by William Fairbairn; from the author.

On the Rolling &c. of Ships, by W. J. Macquorn Rankine; from the author.

Proceedings of the Institution of Civil Engineers; from the Institution.

Report of the British Association for the advancement of Science; from the Association.

Collection of Drawings of the Ecole Impériale des Ponts et Chaussées, Paris; from the Ecole.

Proceedings of the French Institution of Civil Engineers; from the Institution.

Transactions of the Institution of Civil Engineers of Ireland; from the Institution.

Transactions of the Institution of Engineers in Scotland; from the Institution.
Proceedings of the South Wales Institute of Engineers; from the Institute.
Journal of the Architect and Engineer's Society for the kingdom of Hannover; from the Society.
Journal of the Royal United Service Institution; from the Institution.
Proceedings of the Royal Institution of Great Britain; from the Institution.
Transactions of the Royal Scottish Society of Arts; from the Society.
Report of the Manchester Association for the Prevention of Steam Boiler Explosions; from the Association.
Journal of the Board of Arts and Manufactures for Upper Canada; from the Board.
United States Patent Office Report; from the Commissioners.
Report of Parliamentary Committee on Patent Library and Museum; from Mr. Edward A. Cowper.
Journal of the Society of Arts; from the Society.
The Engineer; from the Editor.
The Mechanics' Magazine; from the Editor.
The Civil Engineer and Architect's Journal; from the Editor.
The London Journal of Arts; from the Editor.
The Artizan Journal; from the Editor.
The Practical Mechanic's Journal; from the Editor.
The Mining Journal; from the Editor.
The Railway Record; from the Editor.
The Steam Shipping Journal; from the Editor.
Bust of Mr. William Fairbairn; from Mr. Edward W. Wyon.

The Council have great satisfaction in referring to the number and character of the Papers that have been brought before the meetings during the past year, and the practical value and interest of the communications and the discussions that took place upon them, which form a valuable addition to the Proceedings of the Institution. The Council request the special attention of the Members to the importance of their aid and co-operation in carrying out the objects of the Institution and maintaining its advanced position, by contributing papers on Engineering subjects that have come under their observation, and communicating the particulars and results of executed works and practical experiments that may be serviceable and interesting to the Members; and they invite communications upon the subjects in the list appended and other subjects advantageous to the Institution.

The following Papers have been read at the Meetings during the last year :—

Description of a Machine for Breaking Limestone and Ore at Kirkless Hall Iron Works; by Mr. John Lancaster, of Wigan.

Description of a Horizontal V Pump; by Mr. John J. Birckel, of Liverpool.

On the improved Traversing Cranes at Crewe Locomotive Works; by Mr. John Ramsbottom, of Crewe.

Description of Harrison's Cast Iron Steam Boiler; by Mr. Zerah Colburn, of London.

On the Distribution of Weight on the Axles of Locomotives; by Mr. John Robinson, of Manchester.

On the Mechanical Appliances of the Loch Katrine Water Works for the supply of Glasgow; by Mr. James M. Gale, of Glasgow.

On the Construction and Results of Working of the large Steam Dredgers on the Clyde; by Mr. Andrew Duncan, of Glasgow.

On the Working and Capacity of Blast Furnaces; by Mr. Charles Cochrane, of Dudley.

On improvements in Heavy Tools for general Engineering and Iron Shipbuilding Work; by Mr. James Fletcher, of Manchester.

On the principal Seams of Coal and Ironstone in the Glasgow Coalfield; by Mr. William Moore, of Glasgow.

On the Construction of Blast Furnaces and the Manufacture of Pig Iron in the Cleveland district; by Mr. James George Beckton, of Whitby.

Description of a Coal Cutting Machine; by Mr. Thomas Levick, of Blaina.

On Puddling Iron by Machinery; by Mr. Henry Bennett, of Wombridge.

The Council have particular pleasure in referring to the great success and interest of the Annual Meeting of the Institution that was held in Glasgow last summer, and in expressing their special thanks to the Local Committee, the Chairman Mr. Walter M. Neilson, and the Honorary Local Secretary Mr. J. Wyllie Guild, for their excellent arrangements and the very handsome reception that was given to the Members of the Institution on that occasion; and also their thanks to the authorities of the Edinburgh and Glasgow Railway for the special arrangements granted for the excursions; and to the proprietors of the works that were so liberally thrown open to the inspection of the Members, for the valuable opportunity afforded to the Members for seeing their works. The Council refer particularly to the great advantage afforded to the Members in the admirable opportunity provided them for visiting the important

works of the River Clyde Navigation and the Loch Katrine Water Works; and they offer their special acknowledgments to the President, Mr. Robert Napier, for the great pleasure afforded to the Members by his exceedingly kind and hospitable reception of them on that occasion, at his residence at Shandon. The Council look forward with confidence to the important advantages arising from the continuance of these Annual Meetings in different parts of the country, from the facilities afforded by them for the personal communication of the Members in different districts of the country and the opportunities of visiting the important engineering works that are so liberally thrown open to their inspection on those occasions.

The President, Vice-Presidents, and five of the Members of the Council in rotation, go out of office this day, according to the rules of the Institution; and the ballot will be taken at the present Meeting for the election of the Officers and Council for the ensuing year.

SUBJECTS FOR PAPERS.

Steam Engine Boilers, particulars of construction—form and extent of heating surface—relative value of radiant surface and flue surface in effect and economy—cost—consumption of fuel—evaporation of water—pressure of steam—density and heat of steam—superheated steam, simple or mixed with common steam—pressure gauges—safety valves—water gauges—explosion of boilers, and means of prevention—effects of heat on the metal of boilers, low pressure and high pressure—steel boilers—cast iron boilers—incrustation of boilers, and means of prevention—effects of surface condensers on the metal of boilers—evaporative power and economy of different kinds of fuel, coal, wood, charcoal, peat, patent coal, and coke—moveable grates, and smoke-consuming apparatus, facts to show the best plan, and results of working—plans for heating feed water—mode of feeding—circulation of water.

Steam Engines—expansive force of steam, and best means of using it—power obtained by various plans—comparison of double and single cylinder engines—combined engines—compound cylinder engines—comparative advantages of direct-acting and beam engines—engines for manufacturing purposes—horizontal and vertical—condensing and non-condensing—

injection and surface condensers—air pumps—governors—valves—bearings, &c.—improved expansion gear—indicator diagrams from engines, with details of useful effect, consumption of fuel, &c.—contributions of indicator diagrams for reference in the Institution.

PUMPING ENGINES—particulars of various constructions—Cornish engines, beam engines with crank and flywheel, direct-acting engines with and without flywheel—size of steam cylinder and degree of expansion—number and size of pumps, and strokes per minute—speed of piston—pressure upon pump—effective horse power and duty—comparison of double-acting and single-acting pumping engines—construction of pumps—plunger pumps—bucket pumps—particular details of different valves—india-rubber valves, durability and results of working—diagrams of lift of valves—application of pumps—fen-draining engines—comparative advantages of scoop wheels and centrifugal pumps, lifting trough, &c.—details of pit work of pumping engines at mines.

BLAST ENGINES, best kind of engine—size of steam cylinder, strokes per minute, and horse power—details of boilers—size of blowing cylinder, and strokes per minute—pressure of blast, and means of regulation—construction of valves—improvements in blast cylinders—rotary blowing machines—indicator diagrams from air main and steam cylinder.

MARINE ENGINES, power of engines in proportion to tonnage—different constructions of engines, double cylinder engines, trunk engines—use of steam jackets—dynamical effect compared with indicator diagrams—comparative economy and durability of different boilers, tubular boilers, flat-flue boilers, &c.—brine pumps, and means of preventing deposit—salinometers—weight of machinery and boilers—kind of paddle wheels—speed obtained in British war steamers, in British merchant steamers, and in Foreign ditto, with particulars of the construction of engines with paddle wheels, &c.—screw propellers, particulars of different kinds, improvements in form and position, number of arms, material, means for unshipping, bearings, horse power applied, speed obtained, section of vessel—governors and storm governors.

ROTARY ENGINES, particulars of construction and practical application—details of results of working.

LOCOMOTIVE ENGINES, particulars of construction, details of experiments, and results of working—consumption of fuel—relative value and evaporative duty of coke and coal—consumption of smoke—use of wood and construction of spark arresters—heating surface, length and diameter of tubes—material of tubes—experiments on size of tubes and blast pipe—construction of pistons, valve gear, expansion gear, &c.—indicator diagrams—expenses of working and repairs—means of supplying water to tenders—locomotives for steep gradients and sharp curves—distribution of weight on wheels.

AGRICULTURAL ENGINES, details of construction and results of working—duty obtained—application of machinery and steam power to agricultural

purposes—barn machinery—field implements—traction engines, particulars of performance and cost of work done.

Caloric Engines—engines worked by gas, or explosive compounds—electro-magnetic engines—particulars and results.

Hydraulic Engines, particulars of application and working—pressure of water—construction and arrangement of valves, relief valves—construction of joints—hydraulic rams.

Water Wheels, particulars of construction and dimensions—form and depth of buckets—head of water, velocity, percentage of power obtained—turbines, construction and practical application, power obtained, comparative effect and economy.

Wind Mills, particulars of construction—number of sails, surface and form of sails—velocity, and power obtained—average number of days' work per annum.

Corn Mills, particulars of improvements—power employed—application of steam power—results of working with an air blast and ring stones—crushing by rolls before grinding—advantages of regularity of motion.

Sugar Mills, particulars of construction and working—results of application of the hydraulic press in place of rolls—application of steam and water for extracting the last portion of saccharine matter—construction and working of evaporating pans.

Oil Mills, facts relating to construction and working, by stampers, by screw presses, and by hydraulic presses—particulars of crushing rollers and edge stones.

Cotton Mills, information respecting the construction and arrangement of the machinery—power employed, and application of power—cotton presses, mode of construction and working, power employed—improvements in spinning, carding, and winding machinery, &c.

Calico-Printing and Bleaching Machinery, particulars of improvements.

Wool Machinery, carding, combing, roving, spinning, &c.

Flax Machinery, manufacture of flax, china grass, and other fibrous materials, both in the natural length of staple and when cut.

Rope-Making Machinery—hemp and wire ropes, comparative strength, durability, and cost—steel wire ropes.

Saw Mills, particulars of construction—mode of driving—power employed—particulars of work done—best speeds for vertical and circular saws—form of saw teeth—saw mills for cutting ship timbers—veneer saws—endless band saws.

Wood-Working Machines, morticing, planing, rounding, and surfacing—copying machinery.

Glass Machinery—manufacture of plate and sheet glass—construction of heating furnaces, annealing kilns, &c.—grinding and polishing machinery.

Lathes, Planing, Boring, Drilling, and Slotting Machines, &c., particulars of improvements—description of new self-acting tools—engineers' tools—files and file-cutting machinery.

Rolling Mills, improvements in machinery for making iron and steel—mode of applying power—use of steam hammers—piling of iron—plates—fancy sections—arrangement and speed of rolls—length of bar rolled—manufacture of rolled girders.

Steam Hammers, improvements in construction and application—friction hammers—air hammers.

Rivetting, Punching, and Shearing Machines, worked by steam or hydraulic pressure—direct-acting and lever machines—portable machines—comparative strength of drilled and punched plates—rivet-making machines.

Stamping and Coining Machinery, particulars of improvements, &c.

Paper-Making and Paper-Cutting Machines, new materials and results.

Printing Machines, particulars of improvements, &c.—machines for printing from engraved surfaces—type composing and distributing machines.

Water Pumps, facts relating to the best construction, means of working, and application—velocity of piston—construction, lift, and area of valves.

Air Pumps, facts relating to the best construction, means of working, and application—velocity of piston—construction, lift, and area of valves.

Hydraulic Presses, facts relating to the best construction, means of working, and application—economical limit of pressure.

Rotary and Centrifugal Pumps, ditto ditto ditto.

Fire Engines, hand and steam, ditto ditto ditto.

Sluices and Sluice Cocks, worked by hand or hydraulic power, ditto.

Cranes, steam cranes, hydraulic cranes, pneumatic cranes, travelling cranes.

Lifts for raising railway wagons—hoists for warehouses—safety apparatus.

Toothed Wheels, best construction and form of teeth—results of working—power transmitted—method of moulding—strength of iron and wood teeth.

Driving Belts and Straps, best make and material, leather, gutta percha, vulcanised india-rubber, rope, wire, chain, &c.—comparative durability, and results of working—power communicated by certain sizes—frictional gearing, construction and driving power obtained—friction clutches—shafting and couplings.

Dynamometers, construction, application, and results of working.

Decimal Measurement—application of decimal system of measurement to mechanical engineering work—drawing and construction of machinery, manufactures, &c.—construction of measuring instruments, gauges, &c.

Strength of Materials, facts relating to experiments, and general details of the proof of girders, &c.—girders of cast and wrought iron, particulars of different constructions, and experiments on them—rolled girders—best

forms and proportions of girders for different purposes—best mixture of metal—mixtures of wrought iron with cast.

Durability of Timber of various kinds—best plans for seasoning and preserving timber and cordage—results of various processes—comparative durability of timber in different situations—experiments on actual strength of timber.

Corrosion of Metals by salt and fresh water, and by the atmosphere, &c.—facts relating to corrosion, and best means of prevention—means of keeping ships' bottoms clean—galvanic action, nature, and preventives.

Alloys of Metals, facts relating to different alloys.

Friction of Various Bodies, facts relating to friction under ordinary circumstances—facts on increase of friction by reduction of surface in contact—friction of iron, brass, copper, tin, wood, &c.—proportion of weight to rubbing surface—best forms of journals, and construction of axleboxes—wood bearings—water axleboxes—lubrication, best materials, means of application, and results of practical trials—best plans for oil tests—friction breaks.

Iron Roofs, particulars of construction for different purposes—durability in various climates and situations—comparative cost, weight, and durability—roofs for slips of cast iron, wrought iron, timber, &c.—best construction, form, and materials—details of large roofs, and cost.

Fire-proof Buildings, particulars of construction—most efficient plan—results of trials.

Chimney Stacks of large size—particulars, form, mode of building, cheapest construction, &c.—force of draught, and temperature of current.

Bricks, manufacture, durability, and strength—hollow bricks, fire bricks, and fire clay—perforated bricks, cost of manufacture, and advantages—dry clay bricks—machines for brick making—burning of bricks.

Gas Works, best form, size, and material for retorts—construction of retort ovens—quantity and quality of gas from different coals—oil gas, cheapest mode of making—water gas, &c.—improvements in purifiers, condensers, and gasholders—wet and dry gas meters—self-regulating meters—pressure of gas, gas exhauster—gas pipes, strength and durability, and construction of joints—proportionate diameter and length of gas mains, and velocity of the passage of gas—experiments on ditto, and on the friction of gas in mains, and loss of pressure.

Water Works, facts relating to water works—application of power, and economy of working—proportionate diameter and length of pipes—experiments on the discharge of water from pipes, and friction through pipes—strength and durability of pipes, and construction of joints—penetration of frost in different climates—relative advantages of stand pipes and air vessels—water meters, construction and working.

Well Sinking, and Artesian Wells, facts relating to—boring tools, construction and mode of using.

Tunnelling Machines, particulars of construction, and results of working.

Coffer Dams and Piling, facts relating to construction—cast iron sheet piling.

Piers, fixed and floating, and pontoons, ditto ditto.

Pile Driving Apparatus, particulars of improvements—use of steam power—particulars of working—weight of ram and height of fall, total number of blows required—vacuum piles—compressed air system—screw piles.

Dredging Machines, particulars of improvements—application of dredging machines—power required and work done.

Diving Bells and Diving Dresses, facts relating to the best construction.

Lighthouses, cast iron and wrought iron, ditto ditto.

Ships, iron and wood—details of construction—lines, tonnage, cost per ton—water ballast—steel masts and yards, and wire rope rigging—comparative strength and advantage of iron and wood ships.

Mining Operations, facts relating to mining—modes of working and proportionate yield—coal cutting machines—means of ventilating mines—use of ventilating machinery—safety lamps—lighting mines by gas—drainage of mines—sinking pits—mode of raising materials—safety guides—winding machinery—underground conveyance—stone breaking machines—mode of breaking, pulverising, and sifting various descriptions of ores.

Blasting, facts relating to blasting under water, and blasting generally—use of gun-cotton, &c.—effects produced by large and small charges of powder—arrangement of charges.

Blast Furnaces—shape and size—consumption of fuel—burden, make, and quality of metal—pressure of blast—horse power required—economy of working—improvements in manufacture of iron—comparative results of hot and cold blast—increased temperature of blast—construction and working of hot blast ovens—pyrometers—construction of tuyeres—means and results of application of waste gas from close-topped and open-topped furnaces—preparation of materials for furnace and mode of charging.

Puddling Furnaces, best forms and construction—worked with coal, charcoal, &c.—application of machinery to puddling.

Heating Furnaces, best construction—consumption of fuel, and heat obtained.

Converting Furnaces, construction of furnaces—manufacture of steel—casehardening, &c.—converting materials employed.

Smiths' Forges, best construction—size and material—power of blast—hot blast, &c.—construction of tuyeres.

Smiths' Fans and Fans generally, best construction, form of blades, &c.—facts relating to power employed and percentage of effect produced—pressure and quantity of air discharged—size and construction of air mains—mechanical ventilation and warming of public buildings.

Coke and Charcoal, particulars of the best mode of making, and construction of ovens, &c.—open coking, mixtures of coal slack and other materials—evaporative power of different varieties—peat, manufacture of compressed peat.

Railways, construction of permanent way—section of rails, and mode of manufacture—mode of testing rails—experiments on rails, deflection, deterioration, and comparative durability—material and form of sleepers, size, and distances—improvements in chairs, keys, and joint fastenings—permanent way for hot climates.

Switches and Crossings, particulars of improvements, and results of working.

Turntables, particulars of various constructions and improvements—engine turntables.

Signals for stations and trains, and self-acting signals.

Electric Telegraphs, improvements in construction and insulation—coating of wires—underground and submarine cables—mode of laying.

Railway Carriages and Wagons, details of construction—proportion of dead weight.

Breaks for carriages and wagons, best construction—self-acting breaks—continuous breaks.

Buffers for carriages, &c., and station buffers—different constructions and materials.

Couplings for carriages and wagons—safety couplings.

Springs for carriages, &c.—buffing, bearing, and draw springs—range, and deflection per ton—particulars of different constructions and materials, and results of working.

Railway Wheels, wrought iron, cast iron, and wood—particulars of different constructions, and results of working—comparative expense and durability—wrought iron and steel tyres, comparative economy and results of working—mode of fixing tyres—manufacture of weldless tyres, and solid wrought iron wheels.

Railway Axles, best description, form, material, and mode of manufacture.

The Papers are to be written in the third person, on foolscap paper, on one side only of each page, leaving a clear margin of an inch width on the left side. In the subjects of the papers, extracts from printed publications and questions of patent right or priority of invention are not admissible.

The Diagrams to be on a large scale and strongly coloured, so as to be clearly visible to the meeting at the time of reading the paper. Enlarged details to be added for the illustration of any particular portions, drawn full size or magnified, with the different parts strongly coloured in distinctive colours. Several explanatory diagrams drawn roughly to a large scale in dark pencil lines and strongly coloured are preferable to a few small-scale finished drawings. The scale of each diagram to be marked upon it.

INSTITUTION OF MECHANICAL ENGINEERS.

BALANCE SHEET.

For the year ending 31st December, 1864.

Cr.	£	s.	d.
By Balance 31st December, 1863	2365	15	10
,, Subscriptions from 11 Members in arrear	33	0	0
,, ditto from 495 Members for 1864	1485	0	0
,, ditto from 1 Graduate for 1864	2	0	0
,, ditto from 8 Members in advance for 1865	24	0	0
,, ditto from 3 Life Members	90	0	0
,, Entrance Fees from 62 New Members	124	0	0
,, Sale of Extra Reports	17	10	0
,, Interest from Bank	150	2	0
	£4291	7	10

Dr.	£	s.	d.	£	s.	d.
To Printing and Engraving Reports of Proceedings	526	10	6			
Less Authors' copies of papers, repaid	16	10	6	510	0	0
,, Stationery and Printing				58	12	8
,, Office Expenses and Petty Disbursements				62	19	0
,, Coals, Gas, and Water				20	2	7
,, Expenses of Meetings				62	8	6
,, Fittings and Repairs				8	1	6
,, Travelling Expenses				32	19	6
,, Parcels				4	9	2
,, Postages				57	11	0
,, Insurance				3	10	9
,, Salaries				450	0	0
,, Rent and Taxes				118	13	9
Balance 31st December, 1864				2901	19	5
				£4291	7	10

(Signed) EDWARD JONES, WALTER MAY, } Finance Committee.

26th January, 1865.

MEMOIRS

OF MEMBERS DECEASED IN 1864.

James Allen was born at Poynton near Stockport in 1824, and after serving his apprenticeship with Messrs. Cole, engineers, Bolton, was engaged as an engineer in the construction of the Leeds and Thirsk Railway. Having given his attention for a considerable time to improvements in the construction of the brass fittings of engines and boilers, he subsequently became partner in the brass and copper works of Messrs. Allen Harrison and Co. in Manchester, in which he continued for the last ten years of his life. He was elected a Member of the Institution in 1856, and died on 11th December 1864, in the fortieth year of his age.

William Harrison Barwell was born at Leicester on 3rd November 1822, and at an early age entered the Eagle Foundry, Northampton, belonging to his father, in which he became a partner in 1853, and thenceforth had almost the entire management of the works until his death, which occurred from a sudden illness on 9th November 1864, at the age of forty-two.

William Steel Brown was born at Innerkip near Greenock in 1835. After serving his time under Mr. Kirtley in the locomotive works of the Midland Railway, Derby, he had the charge of an engine station on that line, and subsequently on the Great Northern Railway at the locomotive works, Peterborough, until his appointment in 1861 as locomotive superintendent of the Edinburgh and Glasgow Railway. His death took place after a short illness on 25th May 1864. He was elected a Member of the Institution in 1863.

John Fowler was born at Melksham, Wiltshire, on 11th July 1826. He was at first engaged in the corn trade, but in 1847 entered the engineering works of Messrs. Gilkes Wilson and Co. of Middlesbrough. Whilst in Ireland in 1849 he was impressed with the great necessity that existed for drainage in reclaiming the waste lands of that country, and conceived the idea that some mechanical system for executing drainage work could be introduced, by which the great expense of manual labour might be avoided; and in the following year he joined Mr. Albert Fry in some works at Bristol for this purpose, and commenced experiments which resulted in the successful completion of the draining plough. Although horse power was at first used for these draining ploughs, a very short time elapsed before steam was successfully applied to them; and Mr. Fowler, finding that he was then able to lay clay drainage pipes at any required depth, entered into large draining contracts in the south of England, to which he devoted himself for about five years. During this time he was also studying the application of steam power to the cultivation of the soil, and from 1852 his attention was constantly directed to this subject; the success which attended the application of steam power to draining machinery leading him to the idea of applying the same power to the cultivation of land. A series of experiments which he conducted at Ipswich in 1856 convinced him that this idea was practicable; and he ultimately exhibited a set of steam ploughing machinery at the Chester meeting of the Royal Agricultural Society in 1858, which gained the £500 prize. In 1857 he read a paper to the Institution on steam cultivation, in which he gave an account of the progress of the draining plough to maturity, and of the progress then made and the results attained in the application of steam power to the cultivating plough. Although the desideratum of steam cultivation was now practically effected, most serious obstacles presented themselves against bringing the invention to perfection, not only from unforeseen mechanical difficulties owing to the physical peculiarities of the land in different localities, but also from the very general ignorance of the agricultural classes in reference to engineering. Mr. Fowler's indomitable energy however enabled him to surmount

all the obstacles met with, and the practical application of steam power to agriculture became gradually so much extended, both in England and on the Continent, that in 1861, in conjunction with the late Mr. Hewitson and Mr. Kitson, he established works in Leeds specially devoted to the manufacture of his machines. These works were subsequently extended and carried on by Mr. Fowler up to the time of his death, with his brother Mr. Robert Fowler. He was elected a Member of the Institution in 1857, and died on 4th December 1864 from the results of an accident, at the age of thirty-eight.

John Hedley was born in 1817 near Fatfield in the county of Durham, and served his apprenticeship with Mr. Robert Clark at the Lambton Collieries, and was afterwards manager at the Bishopwearmouth Iron Works, Sunderland. In 1841 he was for a short time engineer at Whitworth Colliery, and thence went to South Hetton and Murton Collieries, where he remained with the exception of a short interval till 1863 when he resigned from ill health. At the Murton Colliery he erected all the machinery with which the well known Murton winning was sunk through the immense feeders of water contained in the sand underlying the magnesian limestone. He was also extensively engaged in general practice as a mechanical engineer and in the valuation of colliery plant; and was the inventor of "ring cribs" for strengthening the cast iron lining of pit shafts, and of an improved system of guides for cages, in which malleable iron rails are substituted for the ordinary wooden slides. He was elected a Member of the Institution in 1858, and died at Newcastle-on-Tyne on 11th September 1864, at the age of forty-seven.

Edwin Marshall was born on 28th October 1814 at Birmingham, and in 1834 commenced business with his father, a timber merchant in Birmingham. In 1848 they began building railway wagons; and in 1850, in conjunction with Mr. Brown, a coach builder, became railway and general carriage builders, and commenced one of the earliest establishments for the construction of railway carriages, as

the firm of Messrs. Brown Marshalls and Co. In 1855 they erected for the purpose the Britannia Carriage Works, at Upper Saltley, Birmingham, where were manufactured the carriage and wagon stock for many foreign railways. Mr. Edwin Marshall died after a long and severe illness on 8th May 1864, aged forty-nine years. He was a Member of the Institution from 1848.

George Mackay Miller was born in London on 7th December 1813, and in 1829 was apprenticed to Messrs. Lloyd, millwrights and engineers, Southwark. In 1835 he was engaged in the office of Mr. John Dixon, then resident engineer under Mr. George Stephenson on the Manchester end of the Liverpool and Manchester Railway; and in 1837 was transferred to Mr. Robert Stephenson's office in London, upon the London and Birmingham Railway. In 1838 he was appointed resident engineer and manager of the London and Greenwich Railway, which he worked for six years. In 1844 he was sent out by Mr. Locke to Jamaica, for the purpose of making and organising the short line of railway from Kingston; and in 1847, when the line was finished, he returned to England. In the same year he was appointed resident engineer and locomotive superintendent of the Great Southern and Western Railway of Ireland, of which 56 miles length was then opened for traffic. In 1849, when the line was opened to Cork, he took the whole charge of the line and works, and became the chief engineer for all departments of the railway; and had ultimately the entire control of nearly 400 miles of railway, including the works and rolling stock. This position he held for nearly seventeen years till the time of his death, which occurred after a short illness on 4th January 1864, at the age of fifty. He was elected a Member of the Institution in 1853.

William Simpson was born in London on 29th July 1809, his father, Mr. Thomas Simpson, being the promoter and founder of the Chelsea and Lambeth Water Works. He devoted himself to the mechanical branch of engineering, and was the active partner in the firm of Messrs. William Simpson and Co., of Pimlico, from

its commencement until the end of 1862, the works being established for the manufacture of steam engines and machinery, especially in connection with hydraulic works. By this firm were constructed the pumping engines on the double cylinder principle, working with high and low pressure steam in combination, now so successfully used by the Chelsea, Lambeth, and New River Water Works; and a paper on the construction and results of working of these engines was communicated through him to the Institution in 1862. He died on 7th May 1864, at the age of fifty-four, by falling from a steamer whilst returning from the Isle of Dogs, where he had recently established some iron shipbuilding and general engineering works. He was elected a Member of the Institution in 1862.

Charles Lingard Stokes was born in Gloucestershire in 1826, and served his time in the locomotive department of the London and South Western Railway with Mr. John V. Gooch. In 1850 he joined the Eastern Counties Railway, and remained there until 1855, when he was appointed locomotive superintendent of the East Indian Railway; in which capacity he was one of the early pioneers of the locomotive system in India, and afforded the government important assistance during the Indian mutiny by his unwearied devotion in working the railway from Calcutta during that eventful period. At the instigation of the Governor General, the late Lord Canning, he constructed two steam vessels on the Ganges for the conveyance of troops on that occasion: the first vessel was built with extraordinary rapidity, and was worked by two locomotives with their engines and boilers complete, adapted with great ingenuity to the purpose. The mental anxiety and exposure suffered during the mutiny, combined with the insidious effects of the climate, caused his health to give way; and he was ultimately compelled to resign his appointment, and returned home in 1862. He died rather suddenly on 19th January 1864, at the age of thirty-seven. He was elected a Member of the Institution in 1857.

William Henry Woodhouse was born at Overseal, Leicestershire, in 1815, and was originally intended for a country life, but his inclination afterwards led him to take up civil engineering as a pursuit. In 1844 he became connected with Mr. Liddell in the construction of the Leicester and Burton branch of the Midland Railway. He afterwards became associated with the Submarine Telegraph Company; and having gained some experience in the laying of submarine telegraph cables in the Irish Channel, went out during the war with Russia in 1854 in charge of the cable which was successfully laid and established as a submarine telegraph between Balaklava and Varna. He subsequently joined the Atlantic Telegraph Company, and went out in 1858 in the "Niagara" for laying the western portion of the cable. Upon his return to England, and pending the completion of the new Atlantic telegraph cable now in course of construction, he was engaged in various civil engineering works. He became a Member of the Institution in 1861, and died in London on 25th June 1864, at the age of forty-nine.

The PRESIDENT congratulated the Members upon the advancing prosperity of the Institution and the rapid progress it had made in the number of Members and increase of funds, and in the value and interest of the papers communicated; he had no doubt it would still continue to advance in prosperity and importance by the united exertions of the Members. He moved that the Report of the Council be received and adopted, which was passed.

The PRESIDENT announced that the Ballot Lists had been opened by the Committee appointed for the purpose, and the following Officers and Members of Council were found to be duly elected for the ensuing year:—

PRESIDENT.

ROBERT NAPIER,	Glasgow.

VICE-PRESIDENTS.

CHARLES F. BEYER,	Manchester.
WILLIAM CLAY,	Liverpool.
ROBERT HAWTHORN,	Newcastle-on-Tyne.
SAMPSON LLOYD,	Wednesbury.
HENRY MAUDSLAY,	London.
JOHN RAMSBOTTOM,	Crewe.

COUNCIL.

EDWARD A. COWPER,	London.
GEORGE HARRISON,	Birkenhead.
EDWARD JONES,	Wednesbury.
WALTER M. NEILSON,	Glasgow.
CHARLES P. STEWART,	Manchester.
JOHN VERNON,	Liverpool.

PAST-PRESIDENTS.

Ex officio permanent Members of Council.

SIR WILLIAM G. ARMSTRONG,	Newcastle-on-Tyne.
JAMES KENNEDY,	Liverpool.
JOHN PENN,	London.
JOSEPH WHITWORTH,	Manchester.

COUNCIL.

Members of Council remaining in office.

Alexander Allan, . . .	Perth.
John Anderson, ...	Woolwich.
Frederick J. Bramwell, . .	London.
Charles Cochrane, . . .	Dudley.
John Fernie, ...	Leeds.
Sir Charles Fox, ...	London.
Edward Humphrys, . . .	London.
Walter May, ...	Birmingham.
C. William Siemens, . .	London.

TREASURER.

Henry Edmunds, ...	Birmingham.

SECRETARY.

William P. Marshall, . .	Birmingham.

The following New Members were also elected:—

MEMBERS.

John Gay Newton Alleyne, . .	Alfreton.
Martin Baldwin, . . .	Bilston.
William Bass, ...	Workington.
Henry Bennett, . . .	Wellington, Salop.
George Henry Benson, . .	Deepcar.
Martin Benson, . . .	London.
David Kirkaldy, ...	London.
Sverier Hakon Lundh, . .	London.
James Robert Mosse, . . .	Mauritius.
Samuel Rideal, . . .	Manchester.
Bernhard Samuelson, . . .	Banbury.
Arthur Sparrow, . . .	Stoke-upon-Trent.
George Arthur Waller, . .	Dublin.
Thomas Walpole, . . .	Dublin.

HONORARY MEMBERS.

Otto Gössell, ...	London.
John Hall, ...	Manchester.

The following paper was then read:—

ON THE RELATIVE ADVANTAGES OF THE INCH AND THE METRE AS THE STANDARD UNIT OF DECIMAL MEASURE.

By Mr. JOHN FERNIE, of Leeds.

The subject of a Decimal System of Measure resolves itself into two distinct questions, the *desirability* of a decimal system, and the *standard of measure* to be adopted as the unit of the decimal system.

The principle of a decimal system of measurement is now considered to be so advantageous and desirable by the practical and scientific men who have entered into the subject, that sooner or later the irregular and inconvenient system hitherto used in this country must be expected to give place to one more suited to the present times. The permissive bill of 1864, which legalised by Act of Parliament the use in this country of the present standards of measure decimalised, and also of the French standard the metre, is the first public step in that direction; and consequently the question as to which standard is to be finally and exclusively adopted for use in this country has now become an important and urgent practical question. The adoption of the Metre system in its entirety, both for measures and weights, has been strongly advocated by a very influential committee, who are actively endeavouring to effect that purpose; and the object of the present paper is to compare the standards for measure of length, and to show the practicability of adopting a decimal system founded on the Inch at present used in this country, and the advantages that the inch possesses over the metre as the standard unit of measure.

The first question of the *desirability* of a decimal system of measure may now be considered settled, and the principle definitely adopted in this country: but the second question of the *standard of measure* is still open, and is a very important one for consideration on account of the number of circumstances affecting it.

The adoption of the Metre has been strongly recommended, and special efforts were made to get it fixed upon as the compulsory standard of measure for this country; but in the decimal bill now passed it is determined only to legalise the use of the metre in addition to the former standards in this country. The grounds on which the adoption of the metre has been urged are, the existence already of a complete decimal system of measure and of weights based on the metre, and its adoption already as the standard of measure by the large and important population of the French empire and several other countries: the object being to obtain if possible a universal standard of measure for the whole civilised world, on account of the great advantages that would attend the universal use of the same system of measures in the rapidly extending international communications.

The consideration of the *standard of measure* involves two distinct classes of requirements that have to be met as far as practicable, which need a separate examination, namely:—those involving *scientific questions* for preliminary investigation; and those that are *practical conditions* necessary to be fulfilled before the object can be really carried out.

The scientific questions involved may be stated as follows:—

1st. The standard to be the one that can be replaced best in case of being accidentally lost.

2nd. The standard to be the one most universal in the character of its basis of reference.

The practical conditions involved may be stated as follows:—

3rd. The standard to be the one best suited for use in decimal subdivision.

4th. The standard to be the one most extensively and influentially in use already, and consequently involving the least alteration of existing measures.

1st. In considering the question of the standard that can be *replaced best* in case of being totally lost by any accident, there appears on examination to be no real choice between the metre and the inch in this respect. The length of the Metre was originally

determined by measuring a portion of a quadrant of the earth's polar circumference; but its length was also referred to the length of a seconds pendulum, on account of the much greater facility for accurately repeating the measurement of a pendulum than the extremely difficult and complicated operation of measuring an arc of the earth's circumference. The length of the metre was consequently defined in 1798 by Borda, one of the commissioners for determining the French national standard, by giving 0·99385 metre as the length of a seconds pendulum at Paris making 86,400 oscillations in twenty-four hours and vibrating in vacuo at the sea level and at the temperature of freezing water.

The length of the Inch was defined in 1824 by the declaration by Act of Parliament that 39·13929 inches is the length of a seconds pendulum in the latitude of London vibrating in vacuo at the sea level and at the temperature of 62° Fahrenheit. Consequently both the metre and the inch can be verified by the same means, the measurement of a pendulum; and indeed the relation between them having been once established, it follows that whatever means is used for verifying the one, whether by the length of the pendulum or any measurement of the earth's surface, is equally available for verifying the other; so that in this respect there is not any choice between the metre and the inch.

2nd. In regard to the second point—the standard that is *most universal in the character of its basis* of reference—the metre was formerly supposed to have a marked superiority over the inch, as it was originally intended to be exactly the 1-10 millionth part of a quadrant of the earth's polar circumference,* the basis of measurement to which it was referred; whilst on the other hand the inch was an uneven fraction of the length of the pendulum. The result however of subsequent and more accurate measurement

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* NOTE.—Or more correctly the 1-100,000th part of a decimal degree of latitude of which 100 degrees made the quadrant, this degree being taken in France and consequently differing in length from a similar degree in other latitudes on account of the polar diameter of the earth being 1-299th part less than its mean equatorial diameter, owing to its spheroidal form.

has been to show an error of 1-6404th part deficiency in the original measurement of the metre, which was effected in 1794 by the measurement of an arc of about 630 miles length, extending through France from the coast at Dunkirk to Formentera on the coast of Spain, the measurement of which was carried out under unusual difficulties in time of war. In consequence of this error in the original measurement for the standard, the length of the metre has now to be defined by an uneven fraction, as is the case in defining the length of the inch. The further result however of recent investigation has been to show that a quadrant of the earth's polar circumference is not, as was previously supposed, a uniform quantity, and it is therefore not a suitable basis for determining a standard unit of measure; for it has been found that the form of the earth at the equator differs from a true circle, its longest equatorial diameter exceeding its shortest by 1-3941th part, and there is consequently a variation in the lengths of different quadrants of the circumference measured from the pole to the equator. As regards the universality of its basis therefore, there is no choice between the metre and the inch.

It has to be noticed that the present legal standard of measure in this country is really an individual standard metallic yard measure, which was legalised by Act of Parliament in 1855; this had been prepared with all possible care by comparison of all existing standards of authority, the former legal standard, a metallic yard measure made by Bird in 1760, having been destroyed by fire in the burning of the Houses of Parliament in 1834. In consequence however of some sources of error having been discovered by subsequent investigations in the former process of measuring the seconds pendulum, all reference is omitted in this last Act of 1855 to the means of verifying the standard by the length of the pendulum, and the only provision made against a loss of the standard is by legalising certain duplicates that were made from it with the greatest care as secondary standards. The present standard of measure is therefore really an individual metallic yard measure, forming the legal standard independent of any reference to another source: and the metre may indeed be considered to be in a similar position, since it is a continuation or

copy of the original metre, which is now known to differ from the measure of the earth's circumference that it was intended to represent, while the amount of error at present ascertained may probably undergo still further correction by future still more accurate observations.

The circumstance however of depending upon accuracy of copying for the preservation of a standard, though theoretically objectionable, is not practically a disadvantage as regards accuracy. For with the extreme degree of perfection now attained in copying measures of length by Mr. Whitworth's process of contact measurement, the accuracy of measurement can be carried as far as one millionth of an inch, which is a considerably higher approximation than can be attained in any present process of determining the length of a pendulum or an arc of the earth's circumference. The writer is informed by Mr. Whitworth that the standard cylindrical gauges supplied by him to engineering and other establishments do not vary 1-10,000th inch in diameter for any size up to 2 inches, and the larger sizes up to 6 inches diameter do not vary 1-5000th inch.

In consequence of the variation in the lengths of the several quadrants of the earth's circumference, a suggestion has been made by Sir John Herschel to adopt the earth's polar axis as the standard of reference, that being the only single or unique dimension of the earth's mass. As this dimension is very nearly 500,500,000 inches or 1-1000th part more than 500 million inches, it has been proposed by him to increase the inch by 1-1000th part and make it then the standard unit of length as the 1-500 millionth part of the earth's polar axis. It has to be observed however in reference to this proposal, that 1-1000th part of an inch is now an appreciable quantity in mechanical work, such as boring rifles, &c.; and the alteration if carried out would involve a loss of one mile in every 1000 miles. Moreover, independently of these practical objections, any such step would really involve a similar mistake to that made in originally fixing the metre, since the results of future more correct measurements of the earth's axis would be likely to require a correction in the fraction expressing the inch, in addition to the

present known error of 1-170,000th part, arising from the actual length of the axis being rather less than 500,500,000 inches, as ascertained by the present measurement.

All these various considerations therefore appear to lead to the conclusion that the best practical course is to refer to an individual standard which will admit of being copied with a very high degree of accuracy, as in the case of the present legal standard in this country.

3rd. The next question, as to the standard *best suited for use in decimal subdivision*, is one to be determined by the relative practical convenience or inconvenience of the principal subdivisions and multiples of the different standards of length.

The old legal standard of measure in this country, the yard, is near the size of the metre, the former being 36 inches and the latter 39·3708 inches. If the yard were subdivided decimally into tenths, hundredths, and thousandths, it would make a scale as inconvenient and difficult of application in this country as the metre scale: but the standard is defined as a yard of 36 inches, and the inch as a unit of measure has important advantages as regards facility of application, and has a special qualification for the purpose as a convenient unit for expressing the smaller dimensions required in mechanical engineering work, since the subdivisions and multiples of the inch predominate in the dimensions of the parts of machinery, &c. For example, a measuring machine extending from 0 to 10 inches gives an ample range to make the requisite templates and gauges with an accuracy up to 1-1000th inch for all the boring and turning work required for locomotives and for stationary engines up to 100 horse power, and for the tools and machines of corresponding size. The larger dimensions above 10 inches are but few in number as compared with those below 10 inches, and are not required to be more accurate than to 1-100th inch; their dimensions can therefore be obtained from a steel rule of 100 inches length divided into inches, tenths, and half-tenths, while the half-tenth of an inch being easily divisible by the eye into five parts gives hundredths of an inch. The writer has found such a range up

to 100 inches amply sufficient for the requirements of one of the largest locomotive establishments, and also for all the purposes of a large ironworks; and with such a system great accuracy of work is obtained, mistakes and misfits are avoided, and a duplicate system of the most perfect kind is established.

For small dimensions the metre is divided into 1000 parts called millimetres, each being equal to ·03937 inch or about 1-26th inch: but in the classes of work in which the finer dimensions of thousandths of an inch are required, the inch has an advantage over the metre in convenience of application as the unit of measure; for dimensions in thousandths of an inch are readily and conveniently expressed and spoken of, but with the metre as a unit such dimensions require the use of millimetres and fractions of millimetres carried to two places of decimals in order to express them. For example, the standard bore of the government rifles, in which a difference of 1-1000th inch in the diameter of bore has to be recognised and expressed, is

·577 inch or 577 thousandths;

but the expression of such a dimension on the metre system would be in the inconvenient form of

14·67 millimetres.

This is a practical advantage of importance in favour of the inch as the unit of measure; for dimensions to 1-1000th inch are now required in regular use for various descriptions of work. For example, in the case of fixing a wheel or a lever upon its axle, the amount of difference in diameter required between boring and turning, in order to ensure the correct amount of tension, is not a thing to be guessed at, but is a definite quantity ranging from 1-1000th to 5-1000ths inch or ·001 to ·005 inch. If in addition to forcing on by hydraulic pressure, as in the case of putting wheels upon their axles, the further step is taken of expanding the external portion by heat and then shrinking it upon its seating, as in fixing levers upon shafts, a very high degree of accuracy in the respective diameters is required, in order to ensure a definite amount of tension: this is especially the case in the manufacture of wrought iron ordnance, where one series of hoops has to be shrunk upon

another, each layer being compressed in proportion to the work it is intended to sustain. These dimensions of 1000ths inch are now readily appreciated and worked to in regular work by means of the system of contact gauges introduced by Mr. Whitworth; they can be measured by any good workman with a pair of callipers, and great advantage in accuracy and facility of work is derived from the system of working to these definite decimal dimensions.

It may also be observed that the inch divided into 1000ths serves very conveniently to express the series of thicknesses known as the wire and metal gauges, as shown in Mr. Whitworth's decimal wire gauge, a specimen of which is on the table, extending from No. 300 or 300 thousandths of an inch to No. 18 or 18 thousandths of an inch.

A decimal scale founded on the inch as the unit would have then for its subdivisions the 100ths and 1000ths inch at present in use; and the first ascending step in the scale would be the substitution of a 10-inch foot for the present 12-inch foot, being a reduction of 1-6th in the present measure. The succeeding measures would be as shown in the following table, taking merely for the sake of comparison a similar nomenclature to that of the metre scale:—

		Inches.				
Milli inch	=	·001	or thousandth of an inch.			
Centi inch	=	·01	,, hundredth ,,			
Deci inch	=	·1	,, tenth ,,			
Inch	=	1	the Standard Unit.			
Deca inch	=	10		$\frac{5}{6}$ foot	of	12 inches.
Hecto inch	=	100	about	$1\frac{1}{4}$ fathom	,,	72 ,,
Kilo inch	=	1,000	,,	$1\frac{1}{4}$ chain	,,	792 ,,
Myria inch	=	10,000	,,	$1\frac{1}{4}$ furlong	,,	7920 ,,
		100,000	,,	$1\frac{1}{2}$ mile	,,	63360 ,,

A corresponding decimal scale applied to superficial measure would be as follows:—

		Sq. ins.				
Square Inch	=	1				
Square Deca inch	=	100	about	$\frac{2}{3}$ foot	of	144 square inches.
Square Hecto inch	=	10,000	,,	$\frac{1}{4}$ pole	,,	39,204 ,, ,,
Square Kilo inch	=	1,000,000	,,	$\frac{1}{6}$ acre	,,	6,272,640 ,, ,,

In carrying out this change of the measures at present in use, it has to be observed that in consequence of taking for the unit the lowest of the present denominations—the inch—the important advantage is obtained that any dimension on the present system can be exactly expressed in the decimal system without any fractional remainder, and the only calculation required for the change is to bring the dimension into inches, which immediately gives its corresponding value in the decimal system. But if any other of the present measures, such as the foot or the yard, were taken as the unit, a troublesome calculation would be required for this purpose, just as in the case of adopting the metre for the unit; and the result would be an inconvenient fractional quantity, with its accuracy depending in many cases on the length to which the decimal was carried.

4th. The last consideration is the standard that is the *most extensively and influentially in use* already, and consequently involves the least alteration of existing measures in its adoption.

The *metre* was established in France in 1840, and is now the measure in universal use throughout the French empire, and also in Belgium, Holland, and Northern Italy. It has also been subsequently adopted and has partly come into use in Spain, Portugal, Italy, and Greece, and also in Brazil, Peru, Chili, Mexico, and other countries in America. The population of the above countries is about as follows, taking the data from the *Almanach de Gotha*:—

			Population.
Metre in universal use	France, Belgium, Holland, and Northern Italy,		50,000,000
Metre adopted and partly in use	European Countries	37,000,000	
	Ditto Colonies	35,000,000	
	American Countries	26,000,000	
			98,000,000
			148,000,000

The *inch* is in universal use throughout the British empire (excepting India) and throughout the North American States. In British India the native standard measure, the "hath," is legalised as 18 inches; and a multiple of the inch is also the standard

measure of the Russian empire, the imperial "sagene" being legalised as 7 feet English. The population of the above countries is about as follows, taken from the same source:—

			Population.
Inch in universal use	British empire (excepting India)	36,000,000	
	North American States	31,000,000	
			67,000,000
Multiple of Inch in use	British India	138,000,000	
	Russian empire	74,000,000	
			212,000,000
			279,000,000

In addition to this excess in the actual numbers of the people now using the inch over those now using the metre, the fact should be considered that the former include the great machinery producers, whose work is already existing in such large quantities in all parts of the world in the form of engines, machinery, railway plant, tools, &c.; such as the tools and machines of Manchester and Leeds, so largely exported to other countries, their cotton and flax machinery, the sugar mills of the West Indies, the steam engines, agricultural engines, and machinery sent to all parts of the world, steamboats, railway plant and machinery, railway bridges and roofs, &c.; the amount of steam engines and machinery alone that has been exported from this country during the last twenty years having reached the value of £49,000,000, and averaging during the last five years about £4,000,000 annually. The large excess in the machinery already made under the inch over that made under the metre system of measure is an important practical consideration, as it must be remembered that the machines sent out to other countries form types of other machines, and that they require repairing and renewing with the same measures with which they were made. In this country the inch is involved intimately in all mechanical engineering work, and is the basis on which the various machines and engines have been built, as the mechanical engineer may be said to think in inches, calculate in inches, and work in inches; mechanical drawings are made to the inch or its multiples, patterns are in inches, the pitches of the teeth of wheels, the sizes of taps and dies, the standard gauges for boring and turning, and the finer

dimensions of every part of every tool, machine, and engine, are all made in inches; and the sizes of all bars of iron and planks of timber are in inches. The inch is also the basis of the data for calculations of strength of materials, sectional areas of girders and framing, pressure of steam, &c., power, velocity, capacity, and weight. The difficulty of effecting any change in the unit now forming the basis of these measures and calculations would therefore be exceedingly great; but in the case of the metre this difficulty is greatly increased by the relation between the metre and the inch requiring a long fraction to represent it with sufficient accuracy for such purposes, thus:—

1 metre is equal to 39·3708 inches and
1 inch is equal to 25·3995 millimetres.

In the following Table are shown, for the purpose of comparison, the corresponding values in millimetres of some of the ordinary fractions of the inch, and the corresponding values of square and cubic inches in square centimetres and cubic millimetres; from which will be seen the extreme difficulty and inconvenience that would arise in attempting to change the inch to the metre system.

1 inch	=	25·3995	millimetres.
$\frac{1}{2}$,,	=	12·6998	,,
$\frac{1}{4}$,,	=	6·3499	,,
$\frac{1}{8}$,,	=	3·1749	,,
$\frac{1}{16}$,,	=	1·5875	,,
$\frac{1}{32}$,,	=	0·7937	,,
$\frac{1}{64}$,,	=	0·3968	,,
$\frac{1}{100}$,,	=	0·2540	,,
1 square inch	=	6·451	square centimetres.
10 ,, ,,	=	64·512	,, ,,
1 cubic inch	=	16·386	cubic millimetres.
10 ,, ,,	=	163·862	,, ,,

Considering the preponderance of the population now using the inch and not the metre, and the extent to which the inch is now spread over the whole world, the difficulties in the way of a change to the metre appear to the writer so insuperable as to amount practically to a prohibition of a decimal system of measure if it is to be based on the metre.

The subject of decimalising the present very irregular and inconvenient system of *Weights and Measures of Capacity* in this country is one of great importance; and great advantages would arise from their reduction to a uniform decimal system. It has been supposed that the metre system has an advantage in basing the system of weights directly upon the measures of length, the kilogramme of 2·2048 lbs. English being intended to be exactly the weight of a cubic decimetre of pure water at its maximum density: but it now appears from subsequent more accurate measurement that this requires some correction, so that the relation between the kilogramme and the metre is not an even one as intended, but an uneven fractional one. There is strictly no choice therefore in that respect between the kilogramme and the pound; and in fact, in the same way as with the definition of the metre or the inch, any weight, such as the English pound, may be defined with equal accuracy for the standard unit.

It may be remarked that if the pound (pound avoirdupois =7000 grains troy) were taken as the standard unit for decimal weights, the important weights of the cwt. and the ton, which now vary in practice, the cwt. between 112 and 120 lbs. and the ton between 20 and 21 cwts. or 2240 and 2520 lbs., might be decimalised as 100 and 2000 lbs. without any very serious difficulty and with important advantage in removing another of the old irregularities in the system of weights and measures; just as in 1841 the imperial and decimal gallon consisting of 10 lbs. of distilled water at 62° Fahr. was substituted by Act of Parliament for the old ale and wine gallons having 102 and 83 per cent. respectively of the same value.

The following are the general conclusions submitted in the present paper in reference to the standard for decimal measure:—

I.—That the inch and the metre are equally eligible for the purpose, as regards the basis of reference on which they are founded; and either of them could be as accurately and readily replaced as the other in case of being lost: since both of them are practically dependent upon the copying of an individual standard,

which can be effected by the present improved means of measurement with a higher degree of accuracy than could be attained in a repetition of the original process of constructing the standard by reference to a natural standard such as a pendulum or an arc of the earth's circumference.

II.—That the metre is not suitable for adoption in this country, on account of its entire difference from the existing measures and the inconvenience that would arise in expressing the smaller dimensions extensively used in mechanical work, &c.; and that the inch is the most suitable measure for the purpose, on account of its being intimately involved in the present data for calculations and dimensions of mechanical work, &c., and from its convenience for expressing the smaller dimensions extensively used. That for larger dimensions the easiest and most convenient decimal change would be the adoption of a 10 inch measure, which would be a reduction of an even fraction of 1-6th from the present foot; and the longer measures being already multiples of the inch, the change would then be at least easier for their decimal adaptation to the inch than for their entire alteration to the metre standard.

III.—That it is very desirable that an alteration should be made in the present system of weights and measures of capacity, for reducing them both to decimal systems; and that these can be based as definitely and conveniently upon the inch as the standard of measure as upon the metre; and that it will be preferable to adopt for the standard a weight that is already in most common use in this country, such as the pound, without attempting to construct any new standard bearing a more simple relation to the decimal standard of length, but differing from all the existing weights.

Mr. Fernie said he had endeavoured to enter upon the subject of the paper without any bias for either the inch or the metre; and after a good deal of consideration of the question he had come to the conclusions given in the paper, in favour of the inch as the standard unit of decimal measure. In the estimates of the population using the inch or the metre he had found some difficulty in obtaining reliable information respecting this for the different countries; and was partly indebted to a paper read by Professor Rankine at last year's meeting of the British Association at Bath, and partly also to a paper by Sir John Herschel on the yard, pendulum, and metre; it was probable therefore that a different view of the relative populations on either side of the question might be entertained by the advocates of the metre system. With regard also to the value of the exportations from England of machinery constructed on the inch system, which had been referred to in the paper, a small deduction had to be made for machinery constructed on the metre system, as a few of the locomotive establishments in this country had had to send out engines made on the metre system to France and Italy; but generally speaking the engines and machinery made in England had been all constructed upon the inch as the standard of measurement. The only instance that he knew of in which the metre had been entirely adopted in this country as the basis for working upon was the manufacture of Giffard's injector for steam boilers, made at the Atlas Works, Manchester. The injector was however altogether a French invention, and the drawings required for its manufacture were all sent over from France in the first instance with the dimensions marked in millimetres; and as the proportions of the parts were so very delicate, it was feared they might be disturbed by turning the measurements into inches, and the metre had therefore been adhered to as the basis of measurement in that particular branch of work. It would certainly be most difficult to induce the French to adopt the inch; but on the other hand he did not think it was practicable to introduce the metre system universally in English engineering workshops, as the expense of the change would be so great and he did not see that there would be any advantage in it at all. He therefore considered

the inch preferable as the standard unit of decimal measure in this country.

The President said that a deputation had been sent to the present meeting from the International Decimal Association, and he hoped they would give their views upon the subject of the paper that had been read.

Mr. James Yates, as a Vice-President of the International Decimal Association, said he had been particularly gratified to find that the views expressed in the paper coincided so fully with those of the Decimal Association, with regard to the value and practicability of the decimal system of measurement; there was indeed little difference of opinion excepting in the ultimate conclusion drawn as to the standard unit for decimal measure, for which the metre was considered by the Association the most eligible. There was no question that the mode of measurement hitherto used in this country was so irregular and inconvenient that it ought to be abandoned, and a uniform decimal system substituted for it; and the introduction of such a uniform system universally throughout the world would be attended with most important advantages, from the rapidly extending international communications. The two practical conditions affecting the choice of a universal standard unit of measure were, that it should be the one best suited for use in decimal subdivision; and that it should be the one causing the least possible alteration in the existing measures. The question was thus brought into a very narrow compass: namely, whether the preference should be given to the inch or to the metre as the unit of measure; the latter being defined by the platinum metre preserved since 1799 in the *Hotel des Archives* in Paris, and the former by the gunmetal yard measure or bar deposited in 1855 in the office of the Exchequer at Westminster.

The course adopted by the International Decimal Association, in order to obtain a solution of this question as to the best unit of length, had been to send a series of eleven questions to all the persons who were supposed to be best qualified to judge upon the subject; and the answers having been received, four meetings were held in London, to which all such persons were invited; and on that

occasion Mr. Whitworth's system of accurate measurement was exhibited and explained. The result of the discussion of the question at the meetings was that a report was drawn up and circulated, in which it was recommended as eminently desirable that the unit of measurement should be of such a length as might be adapted to measure the greatest variety of objects, and in the most numerous cases likely to occur in daily life; and that it should be visible at a glance of the eye, and easily carried about and manipulated: and it appeared that for these purposes the inch or the foot would be too short, and the fathom too long; and that a measure of about the same length as the ell, the yard, the metre, or the second's pendulum was to be preferred, of which there were important reasons for selecting the metre as the universal unit. The inch indeed seemed at the outset very unsuitable to become the basis of a universal system; and although for English mechanical engineers it might be a very convenient measure, yet even for their purposes he was not satisfied that it would be better than the metre, by the use of which he thought all measurements in mechanical work might be made with equal nicety and accuracy. In the ordinary transactions of daily life the commonest and most universal measurements might be taken as those associated with textile manufactures; and the metre being a measure suitable for cases of this kind would be the most convenient for common use and most eligible as the standard unit of lineal measurement. For example, an order for 13 metres of silk or 64 square metres of carpet was simple in expression and would convey a clear conception of the quantity, if the metre system were adopted, and the unit would be very near the yard now used for the purpose; whereas with the inch as the unit, the equivalent expressions of 510 inches length or 99000 square inches respectively were very inconvenient and not very easily conceived. Such illustrations showed clearly the inconvenience of using a small unit; and led to the conclusion that, in fixing a standard unit of measurement, it was necessary not to have regard to any special purpose exclusively. In aiming solely at the small measurements that predominated in mechanical engineering work, the inch might be the best; but when a standard

was required for all sorts of measurement, the inch was in his own opinion unsuitable for general use.

For the purpose of minute subdivision every advantage was presented by the metre which was attainable by the inch ; since the accuracy of minute measurements depended not on the scale, but on the instrument, which could of course be made equally applicable to any scale. The most recent instrument for minute measurements in connection with the metre system was that of M. Perreaux of Paris, which was shown in the Great Exhibition of 1862, and afforded the means of measuring to 1-3000th of a millimetre (about 13 millionths of an inch) ; and for all practical purposes that was probably as minute and exact a measurement as was required. It should be remarked that Mr. Whitworth himself, who had recommended the inch to be adhered to for mechanical engineering work, objected to the prototype yard from which the inch was supposed to be taken, because it could not be seen or used ; and had shown that it was hardly to be called a measure at all, and was inapplicable and of no value whatever in mechanical operations. The Astronomer Royal too had admitted that the chief value of this standard yard was its convenience for geodetic operations. For these purposes however the metre was at least equally eligible ; and the difficulty that was anticipated from converting the present measures of this country to the metre system, on account of the number of decimal places required, would be met by the use of ready reckoners, specially adapted to all the purposes of commerce ; these would be requisite until the metre was fully established in general use, after which the need of any such aids would cease.

With regard to the relative population in favour of the inch and the metre respectively, he believed the numbers given in the *Almanach de Gotha*, as the population at the present time of all the countries in the world, were generally accepted as the best authority on the subject ; and from these data he had come to the conclusion that the population in favour of the metre should be taken as about three times that using the inch, instead of the majority being in favour of the inch as argued in the paper. Russia with a population of 74 millions appeared to have been put down as favourable to the

inch, because it used the "sagene" of 7 feet English or 84 inches. This measure, which was the Russian fathom, had been fixed at a time when the length of that fathom was very uncertain, by Peter the Great, who decided that it should be exactly equal to 7 feet English. It had been stated however by Mr. Kupffer, the imperial superintendent of weights and measures in Russia, that although the inch was known in Russia as the 1-84th part of their standard unit, it was not used by any means in the same manner or to the same extent as the inch was used in England: on the other hand he instanced many points in which the present weights and measures in Russia approached very nearly to the metre system; and he expressed his opinion that it would be far easier for Russia to adopt the metre system than for England to do so, and he decidedly considered the metre system was preferable for Russia to the inch system. A report had also been presented to the Minister of Finance, by the Imperial Academy of Sciences in St. Petersburg, in which the adoption of the metre was recommended for Russia; and there was therefore some ground for saying that Russia was decidedly tending to the adoption of the metre. The different states forming the Germanic Confederation had formerly been exceedingly confused in their weights and measures, and had recently appointed commissioners to devise a uniform system, who recommended the adoption of the metre system throughout all Germany. A meeting of the several representatives was then held at Frankfort-on-the-Maine, when all the states except Prussia agreed to adopt the recommendation of the commissioners; and at length in 1863, when the statistical congress was held in Berlin, Prussia also gave in its adherence to the metre system: thus all Germany might now be fairly reckoned on the side of the metre. Moreover Germany had for a long time past made a partial use of the metre system, the half kilogramme having been employed as the standard unit of weight in the custom house, the post office, the railways, and other public departments. In India also there was a movement going on which was favourable to the metre system, and recent extracts from the *Madras Times* showed that that district of India was considering the subject and

inclining to the metre. On the whole therefore he thought that Germany and Russia should be added on the side of the countries favourable to the metre, and India should at least be omitted from the number for the inch; and the population favourable to the metre would then be more than 200 millions, in comparison with about 70 millions actually using the inch at the present time.

An important movement was now going on in this country for introducing the metre system in education, since it was clear that the system could not be brought into universal use unless it was first taught universally in schools. He had found a widely prevalent desire on the part of schoolmasters and others interested in education to have the metre system taught in schools to all classes of the community, and it was astonishing to see the amount of facility with which the system was learnt. He exhibited a diagram of the measures and weights of the metre system (Dowling's synoptic table), by means of which he was confident any child might be made to understand the principles of the system thoroughly in a few hours; and if the system were taught for three months in any of the elementary schools, the children would become quite familiar with it. But on the other hand it was well known that the present confused tables of weights and measures were a continual torment to the learners, who had no sooner got them by heart than they began to forget them. The metre system however was not intended to be rendered compulsory in this country at present, but to be publicly taught and by that means gradually introduced, and not made compulsory until the nation was fully prepared for it.

He was happy to acknowledge the favourable opportunity that had been afforded by the paper just read for a practical discussion of the subject in one of its many important bearings; and such a course could not fail to contribute to the satisfactory settlement of this important international question.

Mr. F. P. Fellows, as a member of the deputation from the International Decimal Association, observed that in considering any change of weights and measures the subject should be regarded in all its bearings, in relation to all classes of the population, and not in reference to mechanical engineering only; because what

mechanical engineers wanted for their own work might not be so good perhaps for other purposes. Whatever the unit of measure might be, there was no difference of opinion at all as to the great benefit of a uniform decimal system for all weights and measures. It was true that in the earlier stages of civilisation, when calculations were not put down in writing, the binary system would be most readily employed; but with a written scale of figures the decimal system founded upon the basis of the scale was undoubtedly superior to all others. The great disadvantage in his opinion of decimalising the inch, as the unit of measure in England, was that every other measure of length or capacity would then have to be changed, since the inch had no decimal relation to the other measures of length, area, capacity, and weight. Under such a system therefore the inch would be the only one retained of all the English measures, and the rest must all be altered, involving nearly if not quite as much difficulty as an entire alteration to the metre system. The same remark of course applied in taking any other English measure as the unit; and although in relation to decimal measurement the question of the standard unit of measure was in the abstract of secondary importance, yet the practical objection to setting up any other unit instead of the metre was that there would then be two standard units, and the advantages of a universal system would be lost. Hence, if it were on this ground alone, he thought the adoption of the metre system was highly desirable in this country; and it had the advantage of being a system ready made to hand, perfectly carried out, and already tested in actual use. The whole metre system of weights and measures was connected decimally with the metre: the cube of a centimetre filled with water weighed 1 gramme, which was the unit of weight; the cube of a decimetre gave the litre, or unit of capacity; the cubic metre or stere was the unit of cubic or solid measure; and the square of a decametre gave the are, or unit of square or superficial measure. In this way every unit of weight and measure was obtained at once direct from the metre, which was thus the basis of the entire system. The same advantages could not be attained by any other method except under a similar decimal scale;

and hence the desirability of taking at once the same unit as the basis of the system, and thus adopting the metre system in its integrity, with the whole of its weights and measures, and similar designations for the several quantities.

In connection with the question of population, as bearing upon the adoption of the metre as the unit of decimal measure, was the amount of the home produce exports from this country to the countries favouring the metre system and to those using the present English weights and measures. It appeared that in 1861 the value of the home produce exports to countries using the metre system amounted to as much as 55 million £, while the exports to countries using the English system came to only 24 million £; and further, that in the eight years from 1853 to 1861 the exports to the former countries had increased in value from 32 to 55 million £, while those to the latter countries had actually decreased in the same time from 43 to only 24 million £. He therefore thought that any alteration in the weights and measures of this country should be made so as to suit the great bulk of our customers and those who had increased and were increasing their trade with this country to the greatest extent. The question had been brought before the associated Chambers of Commerce, and urged upon this ground; and they came to the unanimous conclusion that in any change it was desirable to adopt the metre system, because it would simplify all foreign transactions. It would also extend to commerce the advantages already experienced in the sciences from the use of a universal nomenclature in each science, whereby scientific men in different countries were enabled to interchange their ideas upon any subject without being minutely conversant with the languages of other countries than their own; and such an advantage in the case of weights and measures was a most important point to be kept in view in making any change.

It had been advanced as a reason for still retaining the inch and using it as the basis of the decimal system in this country that it had existed already from some thousand years. But on the other hand it appeared that the metre system, which had only been established about thirty years, and had been adopted in the first

instance only by a nation whose trade must be considered small in comparison with that of this country, had yet been found so advantageous by other countries that in the extent of its use it had not only overtaken the inch system, which had been established for so long a period, but had rapidly passed it, and was now either used or being adopted by more than twice as large a population as that using the inch. The metre was thus fast ousting the inch; and whether this country assented to the change or not, there was no doubt that all the other civilised European nations would adopt the metre; and if England persisted in adhering to another standard, it would sooner or later be in an isolated position, differing from all the rest of the world.

While a broader view should therefore be taken of the subject than to confine the consideration of it to engineering work, he thought that even in this connection the metre would be found preferable to the inch, in consequence of the simple decimal relation which he had already mentioned as subsisting between the lengths and weights and other measures of the metre system. Thus a cubic metre of water weighed 1 tonne (1000 kilogrammes), and was also 1 kilolitre in capacity: and therefore if it were required to ascertain the weight of a mass of rock, measuring say 6 metres long by 3^{m} wide and 2^{m} deep, the product of these was 36, which would be the weight in tonnes and also the content in kilolitres of a vessel of water of those dimensions; and multiplying this again by the specific gravity of the rock would give at once the weight of the mass of rock of that size. The inch on the contrary had no simple decimal relation to the pound weight, and could have no such relation except by reconstructing the whole of the present tables of weights and measures, which would be better effected by the substitution of the complete metre system at once. He therefore strongly supported the adoption of the metre system in this country.

Mr. C. W. Siemens said he had paid some attention to the subject of the metre system, and had carried out a good deal of work in France with the metre scale, but had not found any inconvenience in working upon that system. His own draughtsmen

easily fell into the habit of working with the metre scale, and he had had frequent opportunities of watching its working in the hands of French workmen. There was one misconception frequently entertained in this country with regard to the metre, namely that as the metre was the basis of the system it must necessarily be taken as the unit of measure in all instances. This was not at all the case in France however, where, although the metre was the basis of the system, the millimetre was really the unit in mechanical engineering, and mechanical drawings were figured not in metres but in millimetres. He found the millimetre was a very convenient unit for setting out small mechanical work; for being equal to about 1-25th inch it was smaller than 1-16th inch and larger than 1-32nd inch, and was therefore just such a dimension as a workman could still readily appreciate in following a drawing. Of course the millimetre without further subdivision would not suffice to measure with such wonderful precision as was attained by Mr. Whitworth's system of contact measurement, which had been carried out in connection with the inch divided decimally. But for such accurate measurements the unit of measure employed was of little consequence, since any unit could be decimally subdivided to such an extent as to give the required degree of accuracy; and under the metre system the millimetre was subdivided for the very minutest descriptions of work into 100 parts called centièmes, each of which was equal to about 1-2500th inch, and was therefore as suitable for very small measurements as the thousandth of an inch.

Moreover independent of the metre being so convenient a measure for ordinary commercial purposes and already so extensively adopted, he thought it deserved serious consideration whether it would be wise to abandon altogether a measure of some such length as the yard or the metre, as would be the case if the inch were taken as the unit of measure. He agreed that in respect to its verification the metre was not an absolute length; but that was really not a matter of consequence, since, if the quadrant of the earth's circumference were measured a hundred times, each measurement would be likely to differ from all the rest; and if the measurement were taken several hundred years hence, perhaps the

earth itself would have slightly altered in size during that period. The verification of the metre was therefore dependent upon the accuracy of copying an original standard, just the same as in the case of verifying the inch; and this original standard would always be referred to, instead of measuring the quadrant of the earth over again. It was nevertheless of some importance that the unit of length should be a measure referable to the size of the earth, because it was then easily applied to geographical and even astronomical purposes; and in this respect the metre had an advantage as the unit of length, in being approximately an even decimal subdivision of the quadrant of the earth's circumference.

He concurred entirely in the desirability of having a system of measure in which there should be a direct decimal relation between lineal, square, and cubic measure, and between these and weight, as had been explained to be the case under the metre system. It had been correctly explained that the metre afforded a very great facility for ascertaining the weight of any bulk of material, its linear dimensions and specific gravity being known. There was then the least demand made upon the memory, since the specific gravity of different substances was all that had to be borne in mind, instead of a number of practical rules having to be recollected, which were applicable to one material only. The product of the cubic dimensions of any substance in metres multiplied by its specific gravity gave the weight of the substance in tonnes, being almost identical with English tons, or in kilogrammes when the decimal point had been shifted three places to the right. Upon the whole he considered it would be far better to adopt the metre system in this country, in accordance with the other nations who were already using it, than to decimalise a separate unit which would never work afterwards in harmony with the rest of the world.

Mr. James Heywood, as a member of the deputation from the International Decimal Association, said that in advocating the metre system before the British Association he had found the statistical section were generally in favour of the metre, but in the mechanical section there was more difference of opinion, and several engineers opposed the introduction of the metre system and

preferred the plan of taking the inch as the basis of measurement. He thought however the probability was that the public feeling of this country would ultimately decide in favour of the metre; because as England was connected with all the rest of the world by trade, it was greatly to her interest that any change should be in harmony with the custom of other great nations. The Anglo-Saxon people had not hitherto taken any decided step in the matter, whilst many of the continental nations had decidedly pronounced in favour of the metre, and its use was widely spread through all those countries. In the North American States however a commission had been appointed to consider the question. Adverting to one point of detail in the two systems, which had been urged on the side of the inch in the paper that had been read, he did not agree in thinking that 14·67 millimetres was a less convenient expression for a rifle bore than 577 thousandths of an inch; on the contrary he was of opinion that for a workman using such measurements it would be easier to take 14 millimetres with only two decimal places following than to take the whole in decimals of an inch to three places. He had been much struck with the observations of Mr. Tite at last year's meeting of the British Association at Bath, upon the results of his experience as an architect in large works on the continent in which the metre system was used: that system had proved so much more convenient in large calculations than the English system that he had always used it since, and recommended it very strongly as a matter of business, since the calculations were all in the decimal system and therefore made with less labour, and required a smaller number of clerks. In Germany there had been meetings of engineers and others practically interested in the public works of the country, and the reports represented them as almost unanimous in favour of the metre system. That system had been gradually working its way into Germany through the railways from France, which carried everything weighed in kilogrammes; and to avoid the trouble of weighing everything over again, the Germans had adopted the kilogramme, which weighed a little more than 2 lbs. The change to the new system was the great difficulty for this country; but the points of dissimilarity between the metre system and the present weights and

measures were not so serious, he thought, but that intelligent workmen would soon become accustomed to the new system; and for the population at large it must be introduced into the schools of the country, so that the next generation might be prepared for a complete change, as he believed the world was moving on in the direction of a universal adoption of the metre system.

Mr. J. Scott Russell remarked that, although he had a great preference for the existing standards of measurement in this country, he did not think that any change which was to be a great advantage and an important boon to the next generation ought to be opposed on the mere ground of its great inconvenience at the present time; and he considered the country at large was greatly indebted to the International Decimal Association for the manner in which they had brought the subject of decimal measurement and the metre system before the attention of the public. He believed that the decimal system would ultimately become universal; and if persuaded that the metre had a fair chance of becoming the universal standard of measure throughout Europe, he would be ready to incur the great inconvenience of making the transition from the present standards, in order to facilitate the transactions of the next generation. Many concurred in this sentiment, which he considered must be regarded as a very liberal concession on the part of mechanical engineers, because there was no other description of work whatever in which half so much trouble and inconvenience would be suffered from a change of measure as in mechanical engineering. No doubt the metre might be inconvenient for the more common transactions of other trades, but the change was a far more serious matter in engineering work, because it would utterly disarrange all the habits of thought of mechanical engineers, who might be said to carry the inch in their eye and to have the foot incorporated in their entire business operations as the existing standards of measure. Under such circumstances an alteration to a new standard involved a great sacrifice, which however he thought mechanical engineers were prepared to make if it could be shown that the metre system was inevitably coming in the next generation, that it would be a great national advantage, and that great good would be effected by

making the change as rapidly as possible. There certainly appeared probabilities of a universal standard of measure for Europe, and it seemed not unlikely that the standard would be the metre.

The metre system possessed unquestionably the great advantage which had been pointed out, of a direct decimal relation between the measurement of any bulk and the weight of that bulk, without requiring anything to be remembered beyond the specific gravity of the substance under consideration. In his own work of shipbuilding he had found that it would be a great help to all calculations connected with ships if there were a habit of thinking in some unit which bore an exact integral proportion to a ton of water: and it was the fault of the present inch and foot that neither of them gave any convenient factor in relation to a ton of water. For a ton of water consisted of 35·955 cubic feet, and the long decimal fraction was so inconvenient that he had been led to get rid of it in his experiments with models by adding so much salt to the water as should make it weigh exactly 35 cubic feet to the ton. It so happened that the water containing that amount of salt was a tolerably fair average of sea water; and he had made all his calculations in shipbuilding upon water of that description, on account of the convenience of the simple factor connecting cubic measure with tons. The metre had in this respect an advantage over the inch or foot, and he thought it was so great an advantage in practice for engineering and shipbuilding purposes, that although he agreed in the advantages of decimalising the inch for mechanical engineering work, he was opposed to adopting any system which would require all measures first to be reduced to inches and then to be transformed to the metre scale for comparison with the rest of Europe. The advantages of decimalising the inch however were limited to the class of work in which the inch was most largely involved as the unit; and he did not think it desirable to go further and attempt to extend the inch system so as to include the measurement of long distances, such as miles, since it was evidently impracticable to think of miles or similar long measurements in inches.

With regard to the manner in which a change to the metre should be effected, he entirely agreed in considering that the proper way was to have the metre system taught at once in all schools so that the next generation might be prepared for its general use, and to urge its simultaneous adoption in all the other European countries in which it was not at present used; and the sooner it could be carried out universally, the better would it be for all pursuits, since a state of transition was attended with many trials and inconveniences. In the meantime the decimal system should be employed as far as possible in connection with the existing weights and measures; and when the ultimate change came, he was confident mechanical engineers would be found ready to incur the great sacrifice which it would involve, in order that the succeeding generation might enjoy the full benefits of the perfect decimal system founded upon the metre.

Mr. Leone Levi, the Secretary of the International Decimal Association, said he had been present at numerous statistical meetings held during the past few years in the principal capitals of Europe, at which statistical information upon a variety of topics had been sent in from the different countries taking part in the meetings; but although the information so contributed was drawn up in the same tabular form in each case for the purpose of comparison, it was found that the differences in the weights and measures of the several countries caused as much trouble in reducing them to the same denominations as there would have been in compiling the tables afresh. The evil was so great that at the very first meeting, held in Brussels in 1853, it was resolved to recommend a uniform system of weights and measures as essential to the advancement of civilisation and international communication. As however this general recommendation produced no effect, a commission was appointed to report upon the weights and measures in the different countries of Europe, and their relative merits and defects; and the result was that at the international statistical meeting at Berlin in 1862 it was resolved to recommend the universal adoption of the metre system. In the same manner at the International Exhibitions both of 1851 and 1862, the jurors who examined the productions of

the different countries, in order to report which were the best and cheapest, found from the same cause that they could not arrive at any decided conclusion. The difficulties surrounding their duty from the differences in the weights and measures employed were so great that they could not help recommending that these differences should if possible be done away with.

Many of the considerations advanced in favour of the metre system were no doubt extraneous to mechanical engineering; but this branch of work could not be treated independently of other departments of industry, since the interests of the whole country were bound up together in the question. Discoveries in other countries in the various sciences, although known at once throughout the civilised world, were yet deprived at present of much of their practical value, from the difficulty experienced in this country in dealing with foreign weights and measures; and foreign men of science were similarly prevented from arriving at correct results, and if they attempted to reduce the English weights and measures into the metre system, great danger of mistakes was incurred and much valuable time wasted. The extent of the difficulty was moreover fully appreciated by Englishmen when they had occasion to travel abroad and by foreigners coming to this country. These and many other general considerations in connection with the subject were common to the whole world, and he thought they led to the inevitable conclusion that a universal system of weights and measures was an object well worth attaining, and therefore worth taking some trouble to attain. Other European nations had got over the difficulty of making the change to the metre system, and he was sure that England, with all the means of education that were at her command, would learn it more easily than any other country; so that the difficulty need not enter into the question at all, and the only matter to be considered was whether the metre system was good and the change desirable.

In originating the metre system, the French nation, who had the credit of practically introducing and establishing it, had scrupulously guarded it against any possible imputation of being merely a French scheme, started solely for the honour and advantage

of their own country. The unit that had been taken as the basis of the system was a natural unit, based upon one of the great dimensions of nature; and the nomenclature of the system had purposely been constructed upon Greek and Latin terms, in order that it might become equally the property of all the nations in the world. Moreover the French academicians engaged in constructing the system had invited the aid and co-operation of a scientific commission from England, in order that there might be no ground for any national prejudice. He therefore thought this question, standing as it did upon a broad enlightened and international basis, well deserved the careful consideration of the English nation.

Mr. J. Fernie thought that, in regard to the estimate given in the paper of the population in favour of the metre or the inch, the Indian empire might properly be taken on the side of the inch, on account of the very large quantity of machinery that was sent out there from this country, which was all constructed upon the basis of the inch. The apparent preponderance of numbers in favour of the metre appeared to be obtained by including countries which at most could only be said to be aiming at the metre; and he thought these could scarcely be admitted into comparison with the countries which might be claimed as having the inch in actual use. The reason why so many other countries had readily accepted the metre system was he believed because they had previously no system at all, and were therefore glad to avail themselves of a complete system which was offered ready made for their use. But this was not the case with England, in which was already established a complete decimal system of subdivision based upon the inch; and as the recent act of parliament had legalised the use of the present weights and measures decimalised, he did not see his way to the adoption of a universal system based upon the metre. As to the metre itself being a natural unit, he had shown in the paper that its supposed advantage in that respect was destroyed by the spheroidal shape of the earth; and the only natural standard that would have the advantage of being a single or unique dimension was the polar axis of the earth, which had already been suggested for the purpose. He was very glad to have had an opportunity of hearing the views

entertained by the advocates of the metre system, who had communicated much useful information upon the subject; and it was only by a full discussion of the question in this manner that the desideratum of a universal standard unit of decimal measure could ultimately be arrived at.

The PRESIDENT thought one of the greatest and most immediate objections to the adoption of the metre system in connection with engineering work was the great expense which would attend carrying it out; and he did not think a proper estimate could be formed at present of the cost that would be incurred. Otherwise he had found those to whom he had spoken on the subject were favourable to the adoption of a decimal system; and he believed that, if the thorough utility of the metre system was made clear to the mechanical engineers, they would in general be most willing to adopt it.

He proposed a vote of thanks to Mr. Fernie for his paper, which was passed.

The Meeting then terminated; and in the evening a number of the Members dined together in celebration of the Eighteenth Anniversary of the Institution.

Plate 1.

STEAM CULTIVATION.

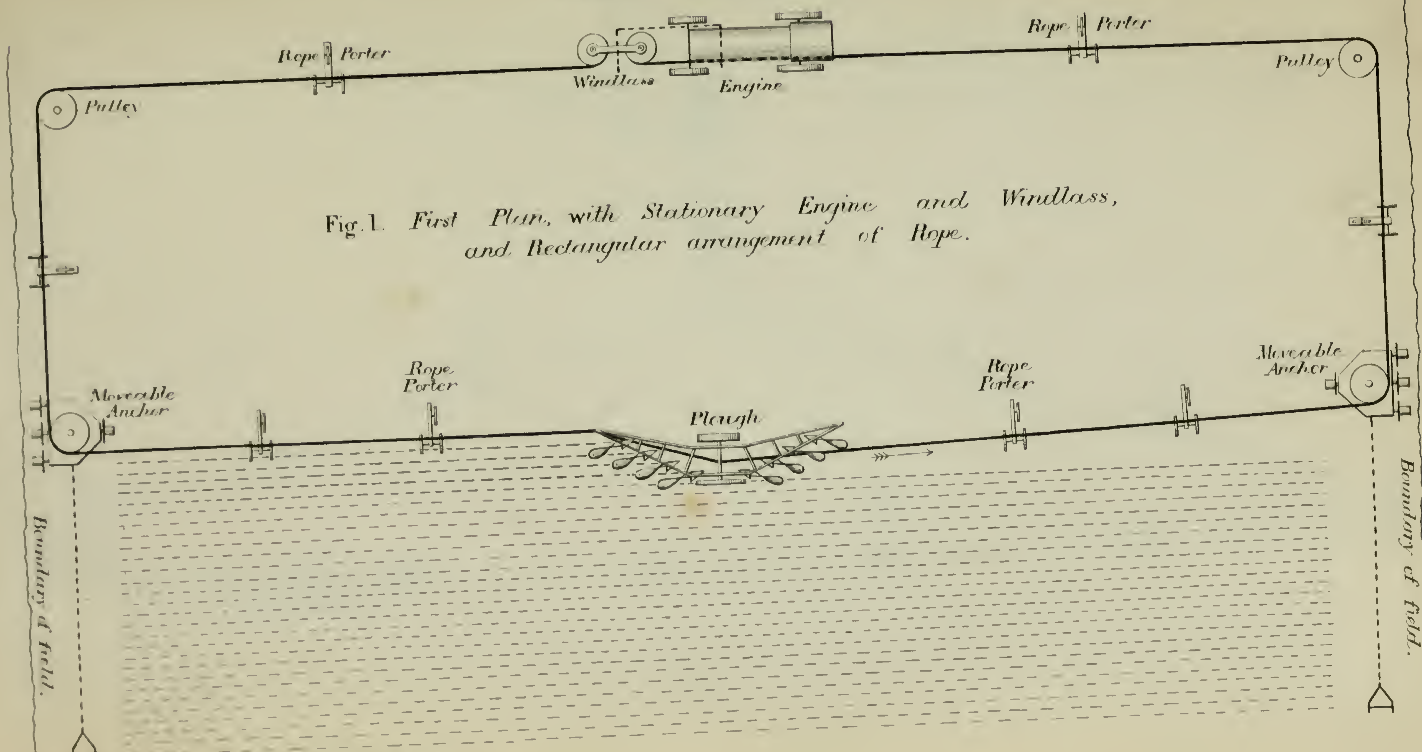

Fig. 1. *First Plan, with Stationary Engine and Windlass, and Rectangular arrangement of Rope.*

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STEAM CULTIVATION.

Fig: 2. *Second Plan, with Stationary Engine and Windlass, and Triangular arrangement of Rope.*

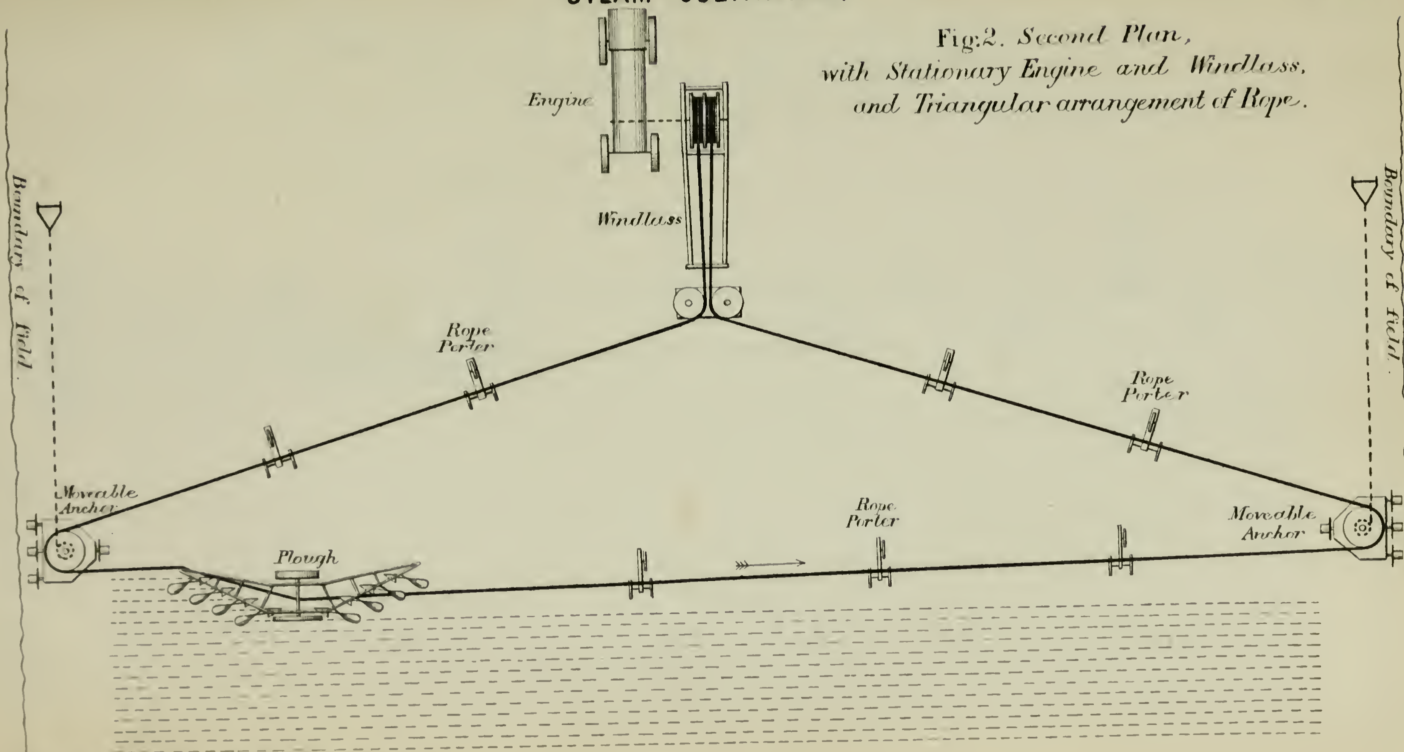
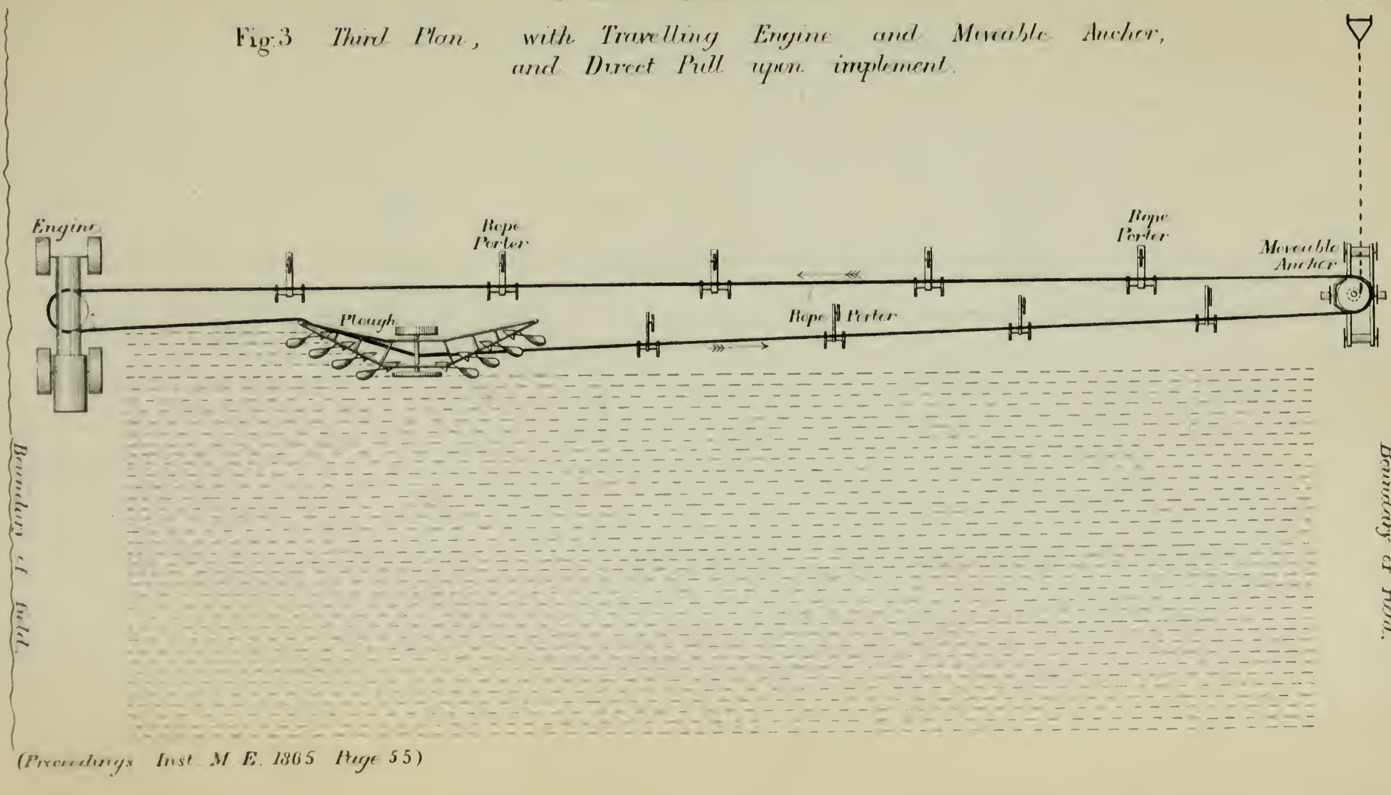


Plate 3.

STEAM CULTIVATION.

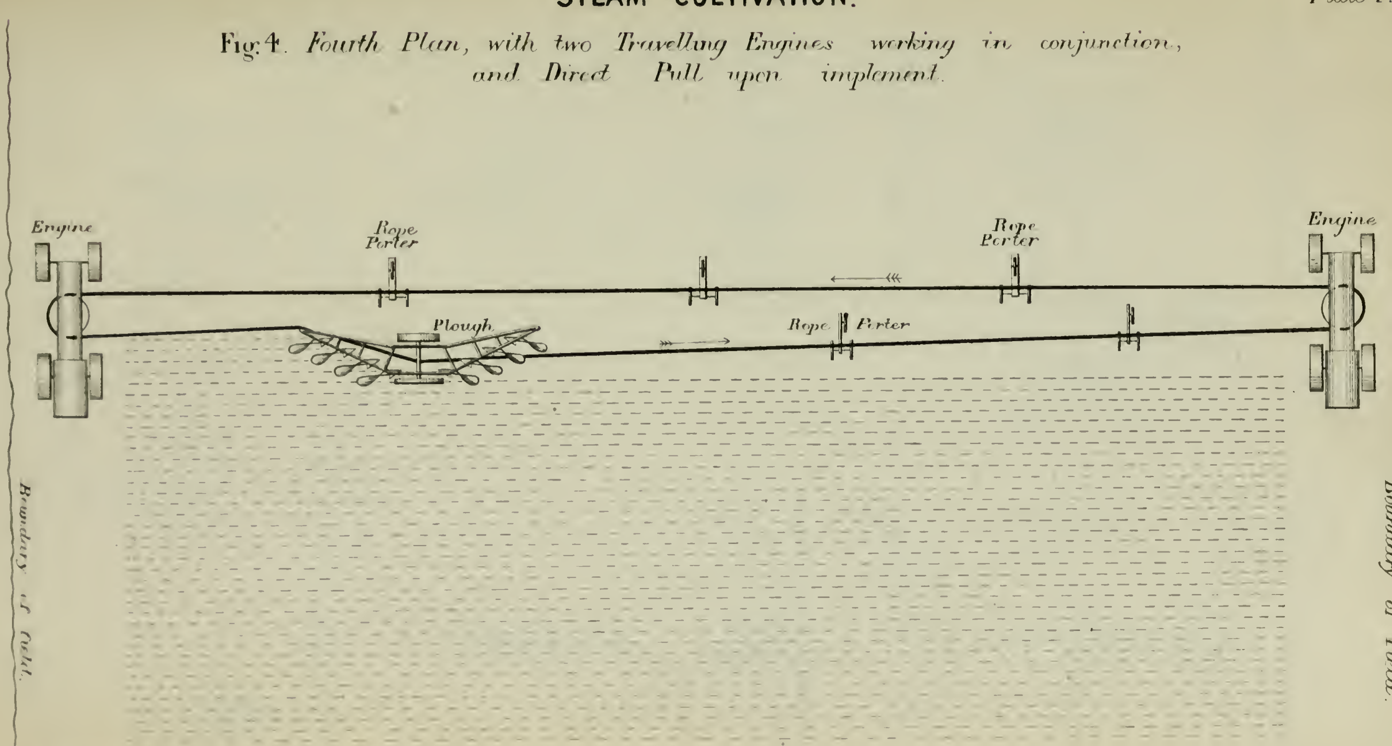
Fig. 3 *Third Plan, with Travelling Engine and Moveable Anchor, and Direct Pull upon implement.*



(Proceedings Inst. M. E. 1865 Page 55)

STEAM CULTIVATION.

Fig. 4. *Fourth Plan, with two Travelling Engines working in conjunction, and Direct Pull upon implement.*



LARGE ROPE PORTER.

Fig. 5. *Side Elevation.*

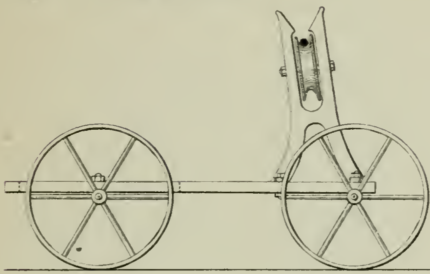


Fig. 6. *End Elevation.*

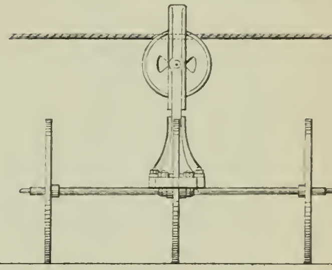


Fig. 8. *Plan of Small Rope Porter.*

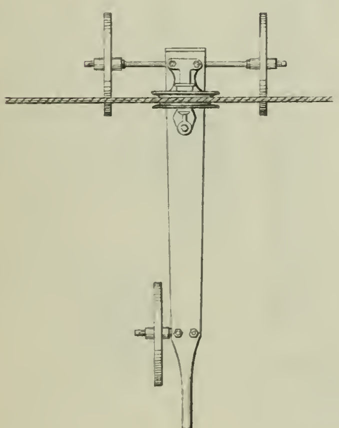
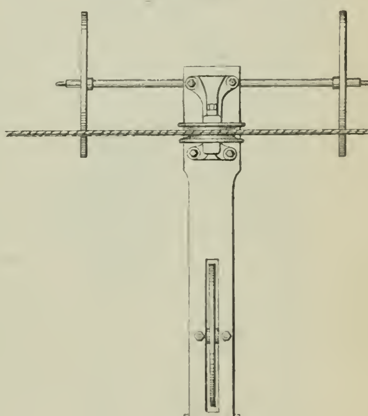


Fig. 7. *Plan of Large Rope Porter.*



SMALL ROPE PORTER.

Fig. 9. *End Elevation.*

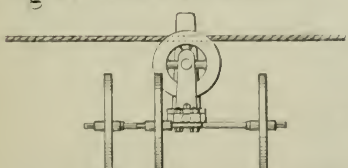
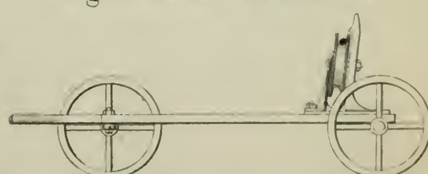


Fig. 10. *Side Elevation.*



Scale 1/30th.

Ins. 12 6 0 1 2 3 4 5 6 7 8 *Feet*

Plate 6.

STEAM CULTIVATION.

MOVEABLE ANCHOR.

Fig. 11. *End Elevation.*

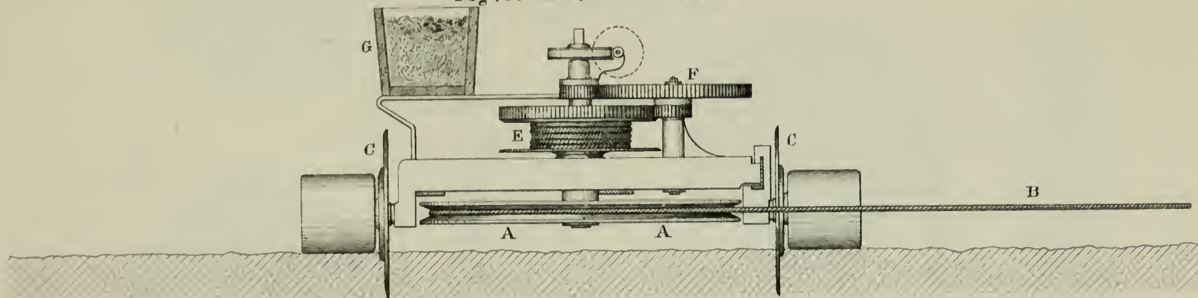
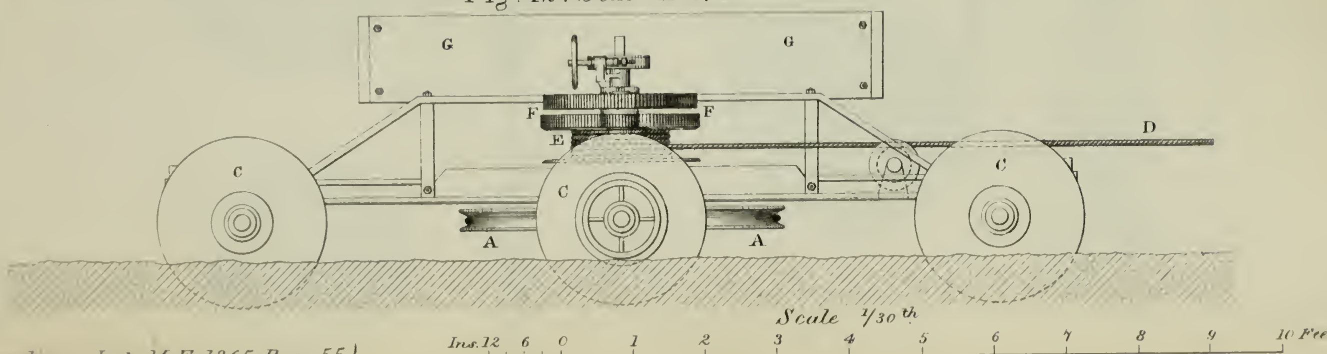


Fig. 12. *Side Elevation.*



(Proceedings Inst. M.E. 1865 Page 55.)

STEAM CULTIVATION.

Plate 7.

DRIVING DRUMS.

Fig. 13. *Four-grooved Driving Drums.*

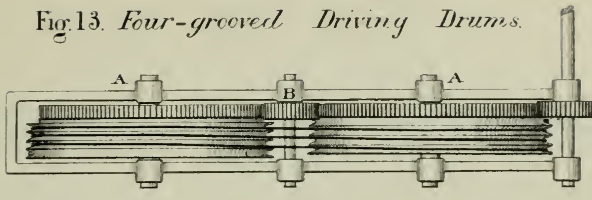


Fig. 14. *Plan.*

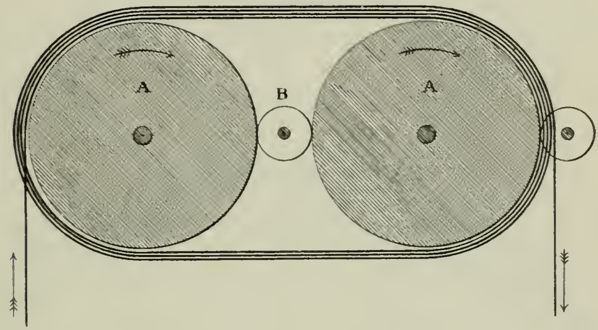
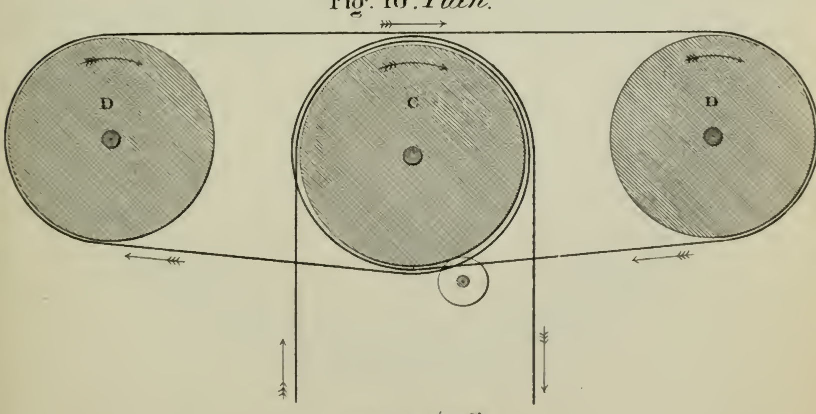


Fig. 15. V-*grooved Driving Drum.*

Fig. 16. *Plan.*



Scale 1/40th.

Ins. 12 6 0 1 2 3 4 5 6 7 8 9 10 Feet

(Proceedings Inst. M.E. 1865. Page 55)

CLIP DRUM.

Fig. 17. *Vertical Section.*

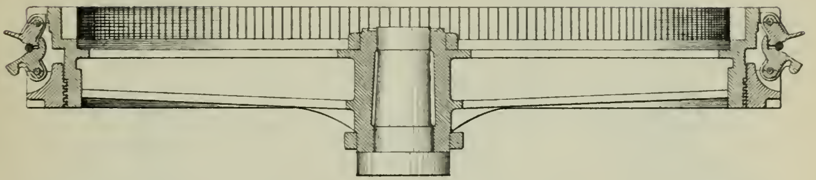
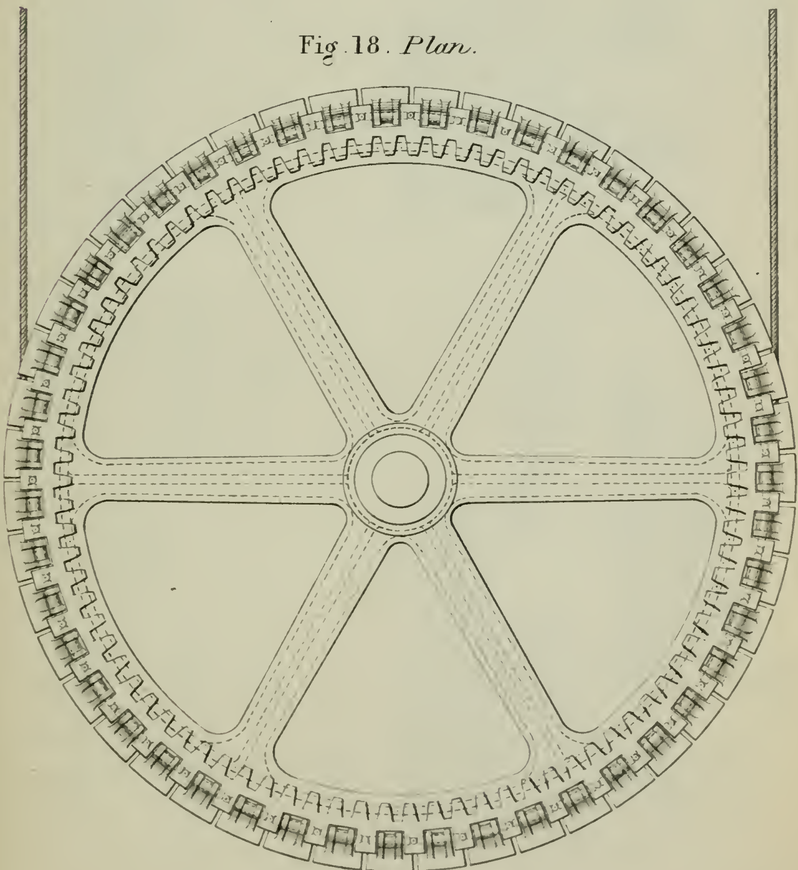


Fig. 18. *Plan.*



Scale 1/16th

STEAM CULTIVATION. *Plate 9.*

DETAIL OF CLIP DRUM, ENLARGED.

Fig. 19. *Plan of Upper Clip.*

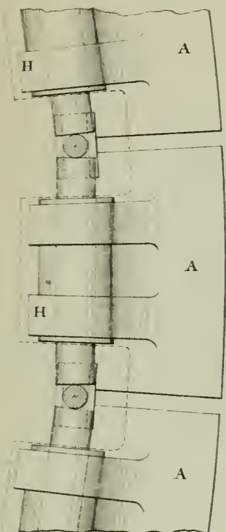


Fig. 20. *Vertical Section, showing clips Closed.*

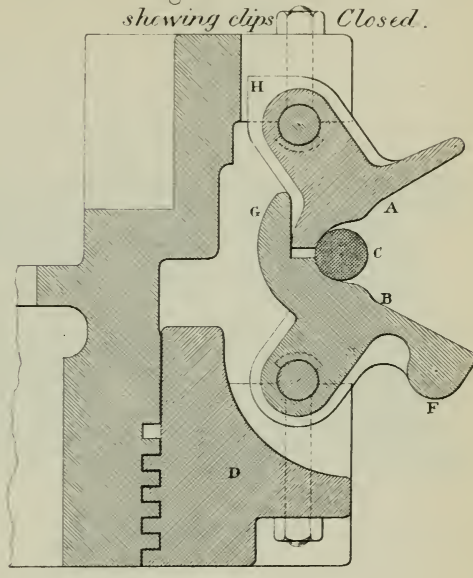


Fig. 21. *Vertical Section, showing clips Open.*

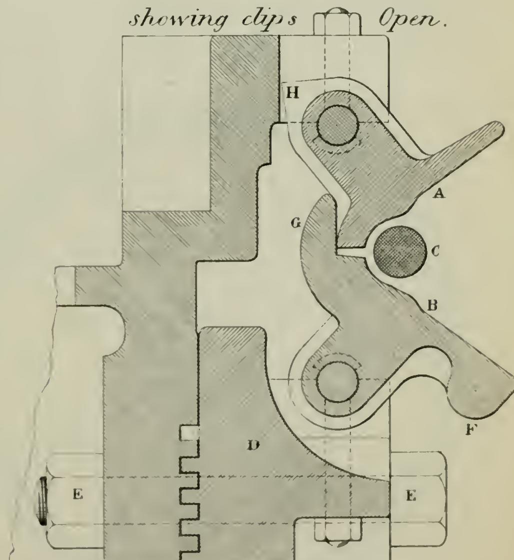


Fig. 22.

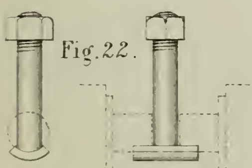
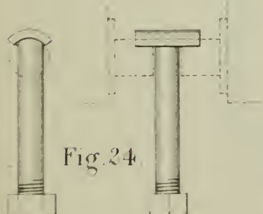


Fig. 23.

Fig. 24.



Scale 1/3rd

0 1 2 3 4 5 6 7 8 9 10 *Inches.*

(*Proceedings Inst. M.E. 1865. Page 55.*)

COMPENSATING BREAK.

Fig. 25. *Plan.*

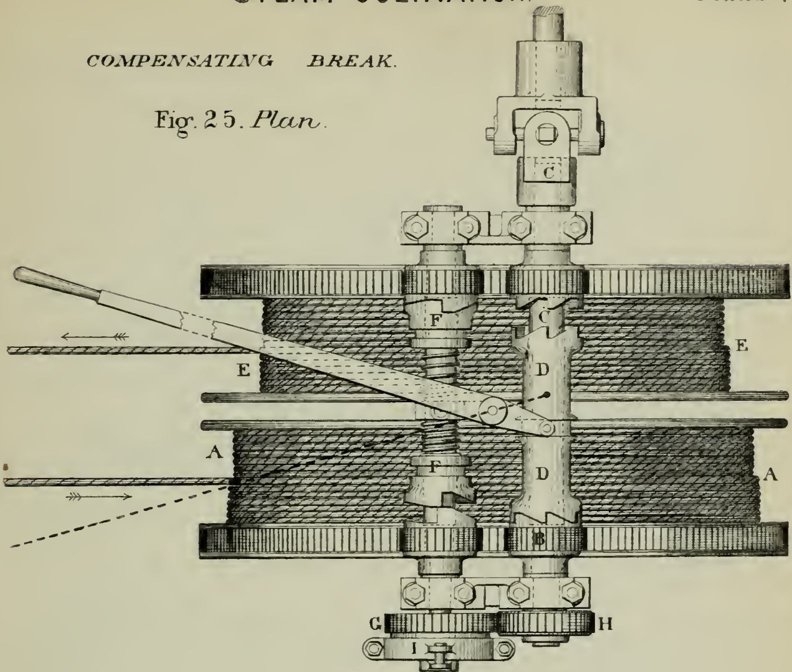
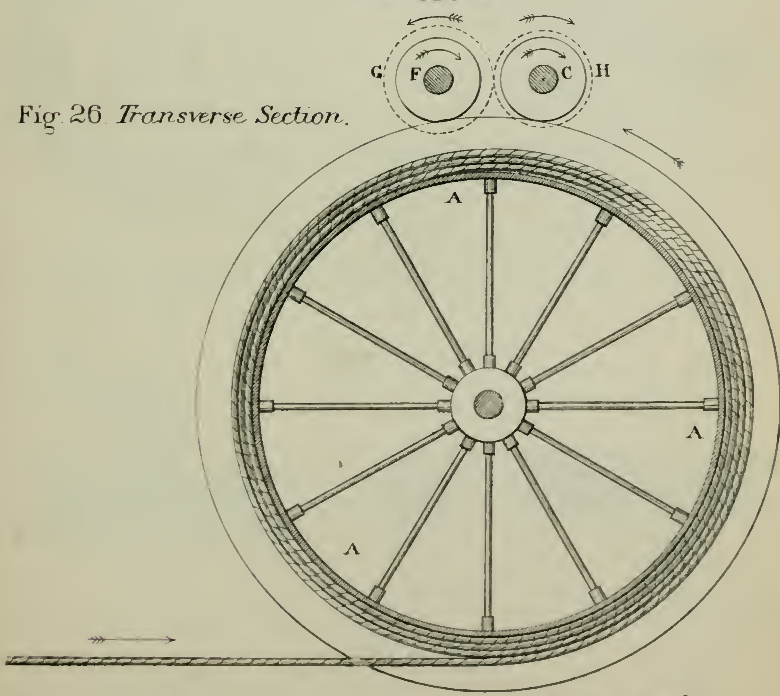


Fig. 26. *Transverse Section.*



(Proceedings Inst. M E 1865. Page 55) *Scale 1/20th*

10 5 0 10 20 30 40 50 *Inches*

SLACK GEAR.

Fig. 27. *Side Elevation of Three Furrow Plough with Slack Gear.*

Scale 1/80th.

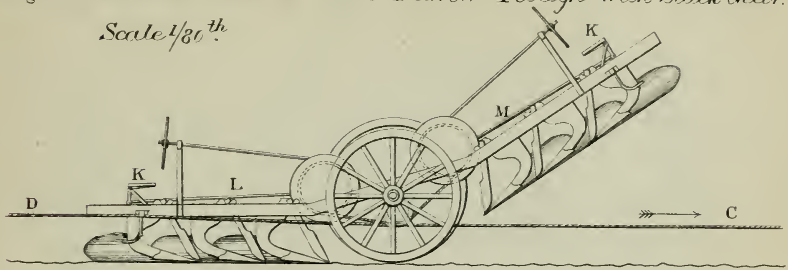


Fig. 28. *Plan.*

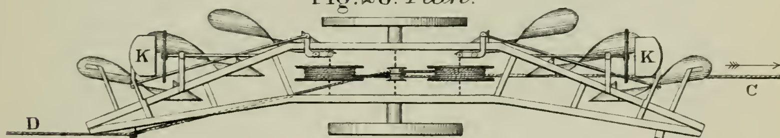


Fig. 29. *Side Elevation of Slack Gear, enlarged.*

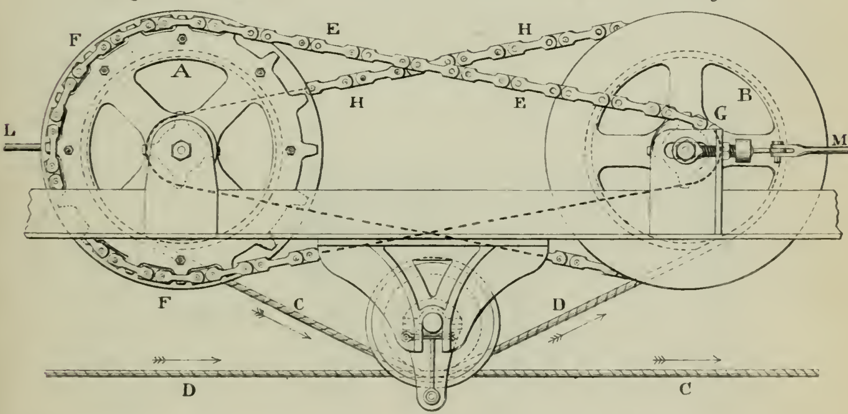
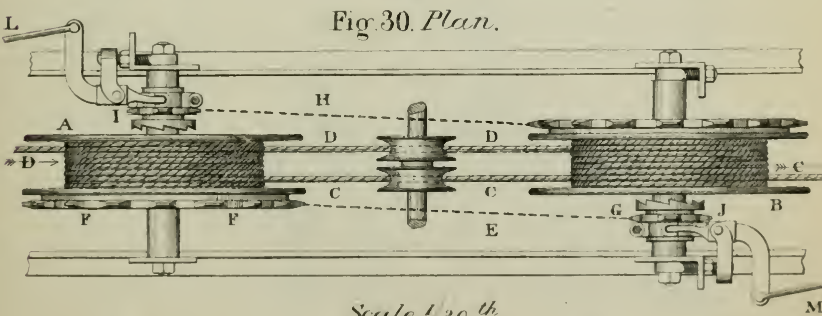


Fig. 30. *Plan.*



Scale 1/20th.

10 5 0 10 20 30 40 50 Inches

(Proceedings Inst. M. E. 1865. Page 55)

STEAM CULTIVATION.

BROAD-RIM DRIVING WHEELS.

Fig. 31. *End Elevation, partly Section.*

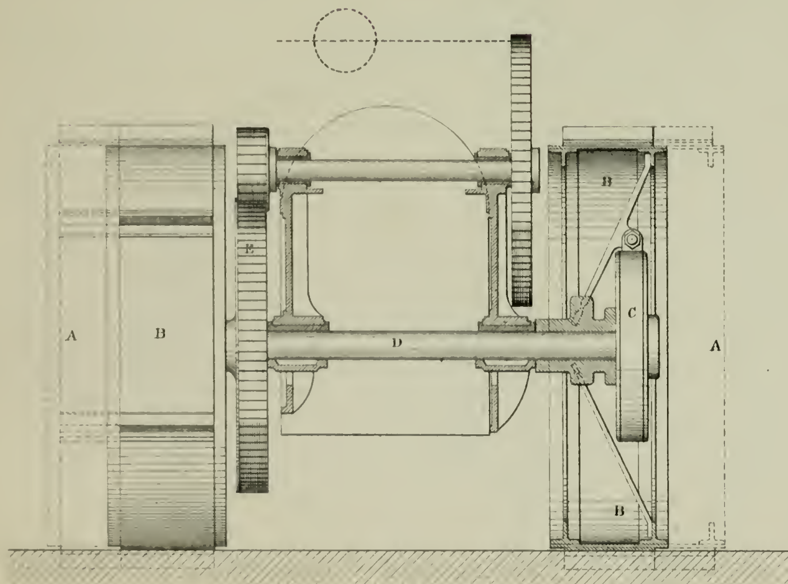
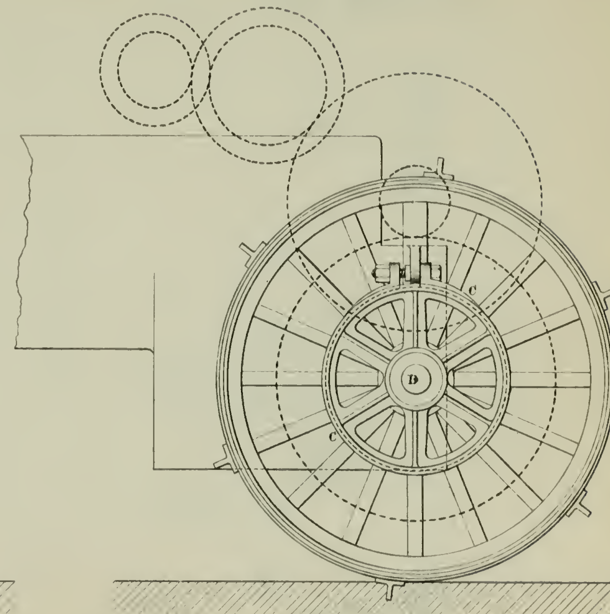


Fig. 32. *Side Elevation.*



Scale 1/30th

Ins 12 6 0 1 2 3 4 5 6 7 8 9 10 Feet.

(Proceedings Inst. M. E. 1865. Page 55.)

COILING GEAR.

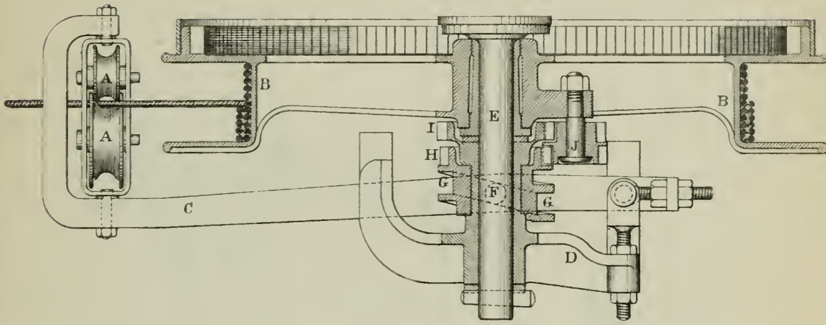


Fig. 33. Vertical Section.

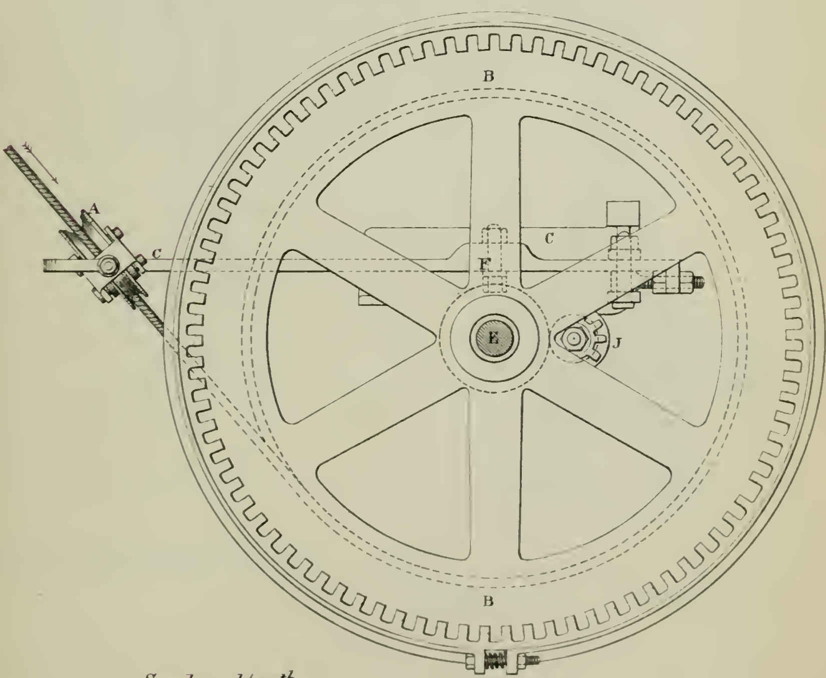
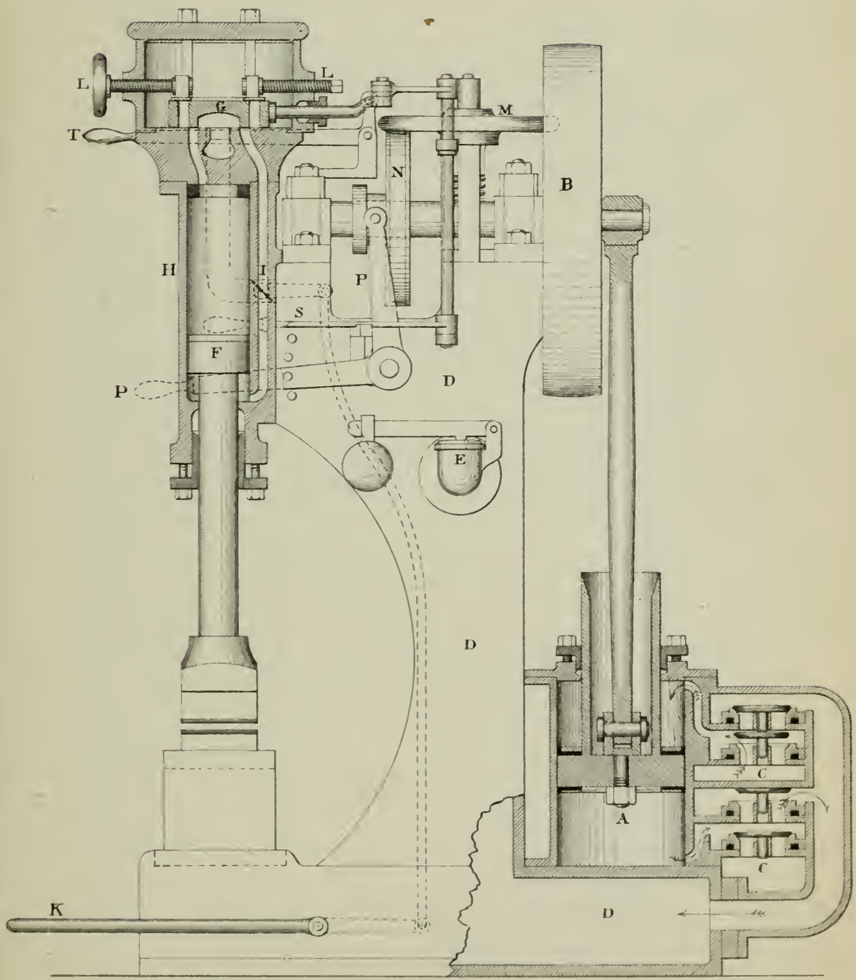


Fig. 34. Plan.

Scale 1/20th

10 5 0 10 20 30 40 50 Inches.

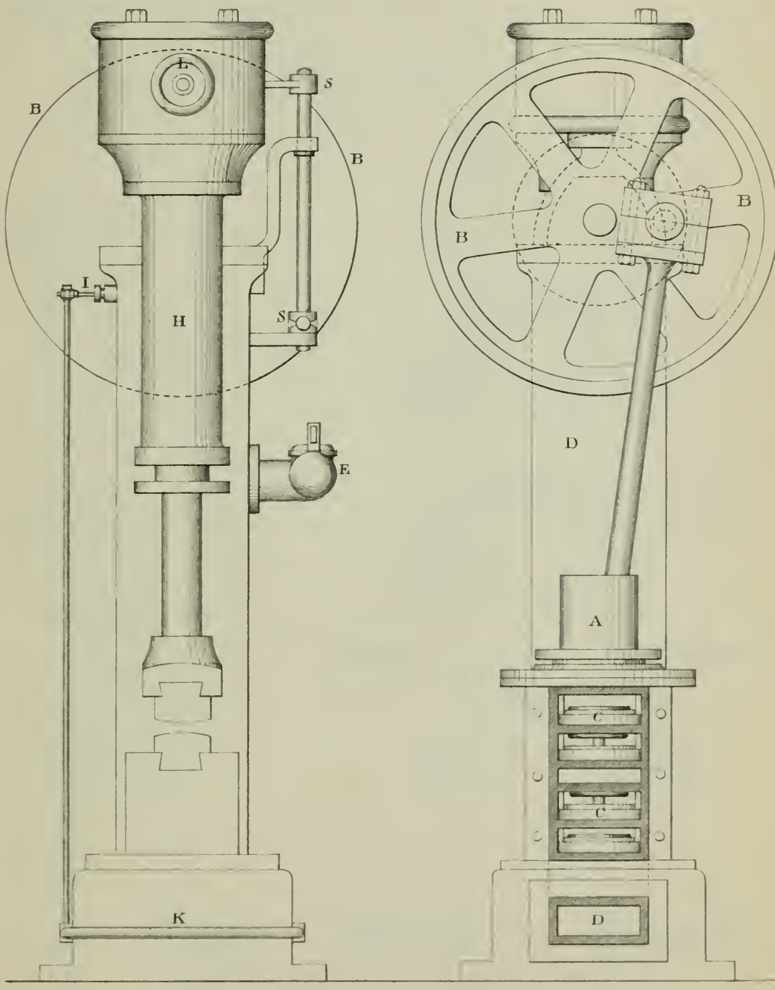
Fig. 1. *Side Elevation, partly in Section*



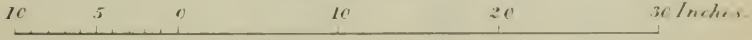
Scale 1/12th

10 5 0 10 20 30 *Inches.*

Fig. 2. *Front Elevation.* Fig. 3. *Back Elevation.*

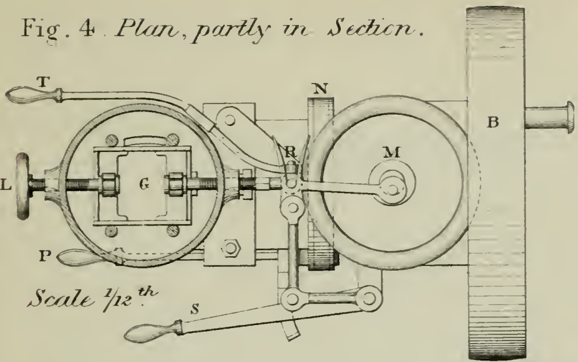


Scale 1/12th



(Proceedings Inst. M. E. 1865. Page 94.)

Fig. 4. *Plan, partly in Section.*



Scale 1/12th.

Fig. 5. *Sectional Plan thro Hammer Cylinder.*

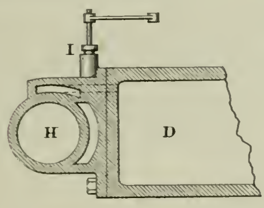
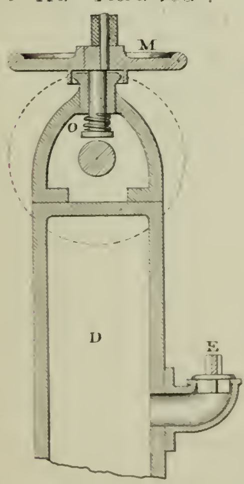


Fig. 6. *Vertical Section thro Air Reservoir.*



Scale 1/12th.

0 10 20 Inches

Positions of Slide Valve, enlarged. Scale 1/6th.

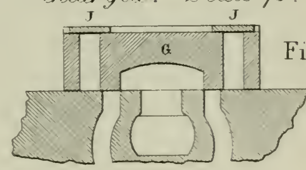


Fig. 7.

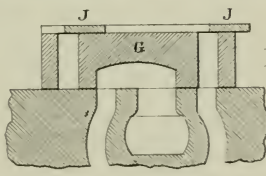


Fig. 8.

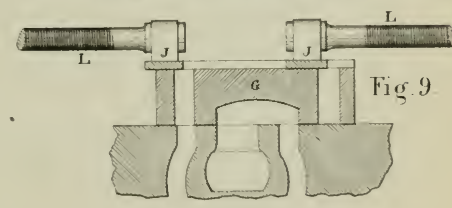


Fig. 9.

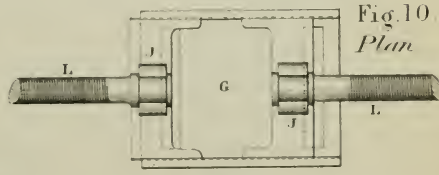
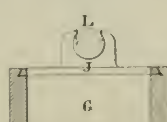


Fig. 10. *Plan.*



Transverse Section.

Fig. 11.

PROCEEDINGS.

4 May, 1865.

The General Meeting of the Members was held in the Lecture Theatre of the Midland Institute, Birmingham, on Thursday, 4th May, 1865; Frederick J. Bramwell, Esq., in the Chair.

The Minutes of the last Meeting were read and confirmed.

The Chairman announced that the Ballot Lists had been opened by the Committee appointed for the purpose, and the following New Members were duly elected:—

MEMBERS.

William Daniel Allen,	Sheffield.
John Bailey,	Dublin.
William Barclay,	Inverness.
Walter Brock,	Glasgow.
Henry Lee Corlett,	Dublin.
Abraham Darby,	Ebbw Vale.
Benjamin Dobson,	Bolton.
Walter Elliot,	Gibraltar.
William Dunn Gainsford,	Sheffield.
William Gibbs,	Wolverhampton.
David Greig,	Leeds.
William Dakin Grimshaw,	Birmingham.
Henry Hyde, R.E.,	Calcutta.
John Jackson,	Alderney.
Joseph Ledger,	Workington.
Frederick Allen Leigh,	Manchester.
Francis Carr Marshall,	Jarrow.
Robert Morton,	Stockton-on-Tees.

William Mallabey Murdock, . .	Northampton.
Alexander Parkes, ...	Birmingham.
William Perry, ...	Wednesbury.
Job Richards, ...	Smethwick.
John Richardson, ...	Gloucester.
William Mander Sparrow, . .	Wolverhampton.
William Stroudley, ...	Glasgow.
Edward Williams, . . .	Dowlais.
Solomon Woodall, ...	Dudley.

GRADUATE.

Edward Edwards Hewett, . .	Derby.

The following paper was then read :—

ON THE APPLICATION OF STEAM POWER TO CULTIVATION.

By the late Mr. JOHN FOWLER, and Mr. DAVID GREIG, of Leeds.

In a paper on this subject read by Mr. Fowler at a former meeting of the Institution on 29th April 1857 (see Proceedings Inst. M. E. 1857, page 57), reference was made to the Draining Plough, first drawn by horse power and afterwards by steam, and to the course of experience that the writer had with that implement, which had led him step by step to the application of steam power to the ordinary purposes of cultivation. In that paper the results of his experience were given for the previous seven years, during which this work had been developed; and in the present paper the subject is proposed to be continued by the results of his subsequent experience in carrying out the application of steam power to cultivation during the last eight years. This paper, which was left unfinished at the time of Mr. Fowler's recent death, has been completed by Mr. David Greig, who had been long associated with him in carrying out Steam Cultivation.

In considering the mechanical problem to be solved in the application of steam power to agriculture, it is requisite before referring to the design of any particular machine to examine the general principles on which the application of mechanical power to cultivation can best be effected. To do this effectually it is necessary to ascertain the nature and extent of the difficulties to be overcome; and these may be stated to be the following:—

I. The irregularities of level in the surface to be acted upon.

II. The varying positions of the machinery upon the ground, rendered necessary as the work proceeds.

III. The difficulty of getting heavy engines of sufficient strength moved about where no roads exist.

IV. The production of a rope of sufficient strength, hardness and elasticity to stand the work.

V. The changes in the state of the soil from the effects of weather.

I.—First with regard to the irregularities of level in the surface of the land to be cultivated.

The first idea which naturally occurs in applying steam power is that of attaching the motive power direct to the implement, as is done in the case of horses. But experience has proved that the power required to move a steam engine over the land, of sufficient power and weight for traction purposes, is quite impracticable, from the fact that such an engine would weigh at least 12 tons, and would in many cases absorb as much as 30 horse power in the mere act of moving itself at the rate of 2½ miles per hour. Moreover when the land gets at all wet and greasy on the top, it becomes quite impossible to make such an engine travel over the soil. Also the compression caused by its travelling over the land would in most cases neutralise the good otherwise effected by the cultivating implement; so that any advantage which there might be in direct action would be more than counterbalanced by the practical difficulties that stand in the way of its adoption.

Under these circumstances it becomes absolutely necessary to convey the power over the surface of the land by means of a rope, allowing the prime mover to stand in the most direct position for its work and exert all its force in accomplishing the operation to be performed. The employment of wire rope for this purpose was at first attended with considerable drawbacks, both from the difficulty involved in the application itself, and from the wear of the rope; the latter was chiefly caused by the amount of friction the rope was exposed to, which involved also a loss of power.

The use of wire rope in the cultivation of the soil was gradually developed from its commencement to its present successful application. The First system of using rope was by placing the engine in a stationary position at the side or corner of the field to be cultivated, as shown in the diagram Fig. 1, Plate 1, and leading the rope all round

the margin of the field; the two ends of the rope were attached to two winding drums at the engine, giving out and taking in the rope alternately, and the plough or cultivating implement being attached to the middle of the rope was hauled backwards and forwards across the field. This rectangular arrangement involved a great deal of fixing of machinery in the field before commencing operations, including fixing the engine and windlass, fixing a pulley or snatch-block at each of the two corners of the field nearest to the engine, and a large number of rope porters or carrying pulleys; it also entailed two moveable anchors, one at each end of the line of traverse of the implement, which had to be shifted by some means each time that the traverse was reversed, so as to lead the implement into a fresh line. The general construction of the Rope Porters is shown in Figs. 5 to 10, Plate 5: Figs. 5 to 7 show the larger kind used for the permanent lines of rope; and Figs. 8 to 10 show the small porters for the rope attached to the implement, which are withdrawn and placed again by boys as the implement passes across the field. In employing such an arrangement of tackle, the consideration of the complication of the parts, the numerous pulleys and frequent bending of the rope over the pulleys, which were of necessity small in diameter, and the great time required for fixing the apparatus, early led the writer to the conclusion that such a plan of applying power could not prove permanently successful; and although it has been extensively used it is now generally superseded by more direct and simple arrangements.

The Second mode of using wire rope, shown in Fig. 2, Plate 2, was merely a modification of the first, and consisted in placing the stationary engine and windlass in the centre of one side of the field, and leading the ropes away diagonally across the field to two moveable anchors placed at each end of the line of traverse of the implement. A pair of horizontal leading pulleys attached to the windlass allowed the rope to pass off at the varying angles which the progress of the work required, until both the moveable anchors came in a straight line with the windlass. By this triangular plan the two fixed pulleys in the corners of the field in Fig. 1 were dispensed with, and fully one fourth of the rope with its requisite porters was

saved. This arrangement was a great improvement on the former, and the encouragement that it elicited led to a further step, which suggested the important principle on which all subsequent machines have been constructed, namely that of direct pull.

The Third plan of working with rope, with direct pull upon the implement, is shown in Fig. 3, Plate 3, and consisted in placing two horizontal winding drums under a travelling engine, which moved slowly along the headland of the field, keeping always in line with the work. The travelling motion was obtained by means of a pinion gearing into a large internal toothed wheel fixed upon one of the carrying wheels of the engine, and connected to it by a friction clip to prevent any risk of injury from overstrain. The rope was stretched from one winding drum of the engine across the field to a moveable anchor on the opposite headland, and then back to the implement, to which it was attached; and another rope from the other drum was also attached to the implement. The work was performed by the engine winding up one drum as it gave off rope from the other, the implement being thereby pulled backwards and forwards across the field.

The Moveable Anchor is shown in Figs. 11 and 12, Plate 6, and consisted of a carriage with a horizontal pulley A mounted on it, round which the hauling rope B of the plough worked, while the sharp-edged carrying wheels C entered the ground and resisted the side pull of the rope. The anchor carriage was moved forward each time of changing the direction of the implement by means of a stationary rope D stretched along the headland and made fast at the end, as shown in Fig. 3. This rope was attached to a small drum E on the anchor carriage, and a slow motion was communicated to the drum from the pulley A by the two pair of wheels and pinions F being thrown into gear; the anchor carriage thus pulled itself along the headland a sufficient distance each time, so as always to keep in line with the implement and engine. The box G on the carriage was weighted sufficiently to serve as a counterpoise to the pull.

The experience gained in this plan of working showed that the principle of direct pull of the engine upon the implement was the correct one; but the cumbersome arrangement of the two winding

drums, and the difficulty of coiling the whole length of rope required for reaching across the field, together with the crushing of the rope arising from the soft material of which it was then made and the small diameter of the drums necessarily employed, indicated the need for a still further modification in the apparatus.

The next step was the employment of an Endless Rope, stretched across the field as in the preceding case; with this difference, that the power was now communicated to the rope by friction, instead of by winding on and off a drum as in the plan last described.

In order to secure such an amount of hold on the rope as to give sufficient pull, it was found necessary to employ two driving drums with four grooves each, as shown at AA in Figs. 13 and 14, Plate 7; and the rope was led four times half round both drums, as represented in the diagram Fig. 14, the two drums being geared together by the pinion B. By this means sufficient hold was obtained to overcome the resistance of the work. In order to meet the variations in the length of the rope occasioned by the irregularities in the boundary of the field, two light barrels worked by hand were mounted on the cultivating implement, to which both ends of the rope were attached, and by these barrels a portion of rope was let out or taken up by hand as required to keep it at the proper degree of tightness. When new, this apparatus worked very well; but the wear and tear of the rope from its numerous bends, and more especially from another cause which required some time to develop itself, rendered it necessary to abandon the plan. This great difficulty was the impossibility of keeping the eight grooves in the driving drums all of equal diameter. The two leading grooves were found to be always wearing at double the rate of the others; and all the grooves having to revolve at the same rate, a constant surging of the rope was occasioned by the difference in speed of the circumference of the different grooves. This involved destructive wear of the rope and loss from friction, and every revolution of the drums caused a further grinding away, thus increasing the errors in the diameters of the grooves. As an instance of the deterioration thus occasioned, it may be mentioned that the apparatus got into so bad a condition

that the engine could not perform one half of the work which was done by it when new.

These evils led to a modification of this plan of driving, by the employment of a single driving drum with two V grooves, as shown at C in Figs. 15 and 16, Plate 7, round which the rope was made to take two three-quarter turns, one in each groove. This was effected by using two guide pulleys DD, one on each side of the driving drum C, which transferred the rope from one groove to the other of the driving drum. In this case, as there was only one driving drum with two grooves in it, instead of two drums with four grooves in each drum, the wear and tear was greatly diminished; and this plan of apparatus, although retaining to some extent the evils of the former, is still working successfully in several places.

The objections still remaining however are the number of bends to which the rope is subjected; and from the grip on the rope being obtained by its forcing itself into the V groove by the tension put upon it, serious wear and tear result. In this case there is a compound surging; for from the point where the rope first touches the drum the pressure forcing the rope into the groove increases as the rope passes round the drum, causing the rope to lie deeper in the groove, whereby it virtually lessens the diameter of the drum; in consequence of which the rope must keep on surging endways at the same time that it sinks deeper into the groove. Although these movements are so small as to be imperceptible to the eye, they are actually taking place continually; and the result is serious wear and tear, from the constant grinding motion over the whole rope in succession.

At this point a mechanical contrivance came to the writer's aid, by which a sufficient bite can be obtained with only one half turn of the rope round the driving drum, whilst the rope is taken hold of in such a manner as to cause no friction or surging whatever. At the same time also the total number of bends of the rope is reduced from five to two, as there is only a single bend at each end of the field, which causes a most important saving in driving power and wear and tear. By this mechanical appliance the rope

was at once enabled to perform double the amount of work that it could with the previous apparatus.

The very ingenious contrivance by which this is effected is termed the Clip Drum, and is shown in Figs. 17 and 18, Plate 8, and in detail to a larger scale in Figs. 19 to 24, Plate 9. It consists of a series of pairs of jaws or clips A and B, hinged round the circumference of the drum close together in a continuous line, forming a complete groove in which the rope C works. Each pair of clips in succession, as it passes round to the point where the pressure of the rope upon the drum commences, closes and seizes hold of the rope, as shown in Fig. 20; and continues to grip the rope throughout the half revolution until reaching the point where the rope begins to leave the drum, when the clips fall open, as shown in Fig. 21, being relieved from the pressure of the rope. The amount of grip is in all cases proportionate to the pull upon the rope, and such as effectually to prevent any slipping.

The only provision requisite to suit the clip drum for working with any size of rope is to adjust the width of opening of the clips to the particular diameter of rope to be driven, by widening or contracting the distance between the centres of motion of each row of clips. This adjustment is effected in a very simple and complete manner by having the lower row of clips B centred upon a ring D, Figs. 20 and 21, which forms the circumference of one half the depth of the drum; and this ring is screwed upon the body of the drum by a thread chased round its entire circumference, so that by turning the ring round in either direction the distance between the centres of the upper and lower clips is simultaneously increased or diminished in every pair to exactly the same extent, all of them being kept in perfectly parallel positions. The ring D is held in the desired position by the bolt E, Fig. 21, which prevents it from turning.

The lower clip B of each pair, having a heavy overhanging lip F on the outside, is enabled to lift the upper clip A by means of a small finger G projecting from its inner end and pressing upon the tail of the upper clip; so that the clips always remain open until receiving the pressure of the rope, and they fall open again

M

and release the rope the moment that the pressure is withdrawn. The stop H on the upper clip coming in contact with the body of the drum prevents the clips from falling open too far. Figs. 22 to 24 show the bolts that serve as keeps for holding the ends of the pins on which the clips are centred.

The action of the clips is thus just similar to the closing of a hand upon the rope, laying hold at once so firmly that the rope cannot slip, and retaining this hold uniformly until the rope is released altogether by the opening of the clips; so that all friction or surging from an imperfect hold is avoided, as well as any shifting of the rope at the beginning and end of its contact with the drum, such as is inevitably the case in round or V grooves. At the same time by means of the ring D on which the lower row of clips are centred, the hold upon the rope can be adjusted to any desired amount according to the power required to be transmitted; and it can be absolutely depended upon, when once adjusted, to continue working uniformly with the same amount of hold.

An important practical advantage found to result from the working of this clip drum is that the rope is subjected to a continual pressure upon its sides whilst passing round the driving drum, thus avoiding all tendency to the rope being flattened by the pull, as in an ordinary round-bottomed groove where the pressure of the rope is upon the bottom of the groove only. Also the groove in the clips being so curved as to fit the rope closely round a considerable portion of its circumference, the pressure preserves the form of the rope and serves to consolidate it, by continually closing down all protruding wires and preventing the deterioration of the rope by such parts being caught in passing the subsequent guide pulleys. In the working of this apparatus it will be seen from Fig. 3 that one half of the total length of rope is never in contact with the driving drum, the other half alone being passed round it backwards and forwards successively; and in many cases the actual result has been that the portion of the rope which passes round the drum and has all the work to do of transmitting the hauling power has lasted longer than the other portion which has no such work to do but is simply exposed to the bend round the

pulley of the moveable anchor on the opposite headland, the friction from the guide pulleys being exactly the same in both cases. Another important advantage is that no tension is required upon the rope leaving the drum; all that is requisite is that the rope be taken away and not allowed to kink.

It may be remarked here that these advantages of the clip drum render it specially adapted for use in other positions where a rope is the medium of conveying power; and the saving that it has effected in the wear and tear of the rope employed in cultivation has been fully corroborated by the result obtained in its use for other purposes. It is believed that the action of the clip drum is mechanically correct, and that it will be found highly advantageous for general application in transmitting power by means of ropes.

II.—The second point of difficulty for consideration is the continually varying positions of the machinery upon the ground, rendered necessary as the work proceeds; in consequence of which it is necessary for some means to be provided whereby the ropes will admit of the two extreme points being moved nearer together or further apart as the varying boundary of the fields may require. With a pair of winding drums this is easily effected by not allowing the unwinding drum to begin giving off rope until the rope becomes tight in each case. For this purpose a heavy break has to be applied to the paying-out drum to save the rope from trailing on the ground; for if the rope is not kept from touching the ground a serious loss of power is the result, as the difference in draught required to pull a rope lying on the ground and one properly carried is as much as ten to one. Hence it becomes a very important point that the rope should be efficiently carried off the ground, and this is a matter to which the writer has given considerable attention.

Figs. 25 and 26, Plate 10, show the construction of the Compensating Break that is employed when a pair of winding drums are used, so as to compensate for changes in the length of rope that is required as the work proceeds. The winding drum A

is driven by the pinion B, which is coupled to the driving shaft C by the clutch D; but the driving shaft is geared to the paying-out drum E by means of the second shaft F having corresponding pinions at each end, so as to allow the two drums to run in opposite directions. The two pinion shafts C and F are however made to revolve at slightly different speeds, by the two outside pinions G and H that gear together being of different size, the pinion H being 1-9th smaller than the other; and consequently the paying-out drum E is compelled to revolve 1-9th slower than the winding drum A. This causes the slack in the rope to be all taken up by a few revolutions of the drums; and further strain on the rope is prevented by the pinion G being connected to its shaft by a friction break I, so that it is allowed to slip on the shaft. The rope is thus kept constantly stretched tight by the friction of the break I.

When the endless rope and clip drum are employed for working the implement, instead of two winding drums, a very ingenious and efficient plan has now been adopted, whereby the rope is kept tight without any loss of power; the slack of the rope is taken up or more rope is given off as the field may require, and the implement cannot be started until the rope is tight. This is effected by means of what is termed the Slack Gear, which is shown in Figs. 27 to 30, Plate 11. It consists of two small barrels A and B mounted on the plough, and connected by gearing with a relative speed of five to one, so that the pulling rope C in drawing off 1 foot length of rope from the barrel A winds up 5 feet of the slack rope D on the other barrel B, until all the slack is taken up. The implement then starts at once when the rope becomes tight, and on its arrival at the other end of the field the act of the man taking his seat at the other end of the implement reverses the action of the barrels, so that what was the slack-rope barrel B becomes the pulling one and *vice versâ*. The driving of the barrels A and B is effected by a pitch chain E, which passes over a wheel F of large diameter on the pulling barrel A and over another G of one fifth the diameter on the slack barrel B; a second chain H being placed on the opposite side of the barrels, working over a pair of wheels of corresponding sizes to the former but reversed in their relative positions. The self-acting levers and

clutches I and J are both kept in gear by springs, but are thrown out of gear alternately by the act of the man taking his seat upon the seat K, Figs. 27 and 28, first at one end and then at the opposite end of the plough, and by that means pulling the rod L or M. The same action is thus obtained in whichever direction the implement is travelling, one of the chains E or H with its pair of driving wheels being always in gear with the rope barrels, whilst the other is out of gear.

The effect of this slack gear is to maintain under all circumstances a ratio of five to one between the tension of the pulling rope and that of the slack rope; and consequently whenever the working distance between the engine and the moveable anchor is diminished by the field narrowing, whereby the tension on the slack rope is diminished, this is simultaneously compensated for by the pulling barrel A causing the slack barrel B to wind up the slack rope until its tension is brought up to the fixed ratio of 1-5th of that of the pulling rope. In the opposite case, when the tension of the slack rope is increased above that ratio, owing to the working distance being increased by the field widening, the slack barrel B unwinds until the proportion is restored; and as the pulling barrel A winds up at the same time at 1-5th the rate of the slack barrel unwinding, the implement is propelled forwards to that extent in excess of the direct pull of the engine upon it. The object is thus attained of keeping the rope constantly tight, so as to carry it clear of the ground, however great or sudden may be the variations in its working length caused by the irregularities in the outline of the field; and this is effected entirely by self-acting means without any attention being required on the part of the man and without any loss of power. An advantage arising from the use of the slack gear is the elasticity thereby afforded to the rope, should the progress of the implement be obstructed by its coming in contact with stones or roots in the ground; in this case the rope not being absolutely tight has a margin for taking up further slack, which acts as a spring, easing the strain caused by stopping the implement suddenly.

III.—The third difficulty to be considered is that of getting heavy engines of sufficient strength moved about over the ground where no roads exist.

This has been a serious drawback to the introduction of steam cultivation, and one which has led to more breakage of tackle and machinery than all the action of the machinery in performing its work of cultivation. Two causes have contributed to this result: namely, a mistaken idea at first prevailing that lightness was an essential point, which led to paring down the metal in all parts of the machinery; instead of making the machinery so strong that it could not be broken by the full steam power, and then increasing the width of the carrying wheels to such an extent as to ensure carrying the engine over the wettest fields. The other mistake was that the speed of working on the road wheel was not reduced sufficiently, so as to allow the engine sufficient leverage to get out of any difficulty that it might happen to get into; and the want of judgment on the part of the men using these machines often led to their being put in places of quite unnecessary difficulty.

The first of these mistakes has now been met by making the machinery so strong that the steam when full on is the weakest part of the whole machine. This has naturally led to great weight; but that is no real obstacle, provided the carrying power of the wheels is increased in proportion to the increase of the weight to be carried. In fact the weight is an advantage in steadiness for working, so long as the machine can be kept from sinking too much into the ground. Carrying wheels are now being made for special circumstances as much as 30 inches wide on the rim, as shown in Fig. 31, Plate 12, where the dotted lines A A show the portion that is added to the ordinary 20 inch wheels B B; and these wheels have been proved to carry a 12 ton engine over any land in a fit state of cultivation. The wheels are driven each separately by means of a friction clip C, which prevents any risk of breakage from excessive strain of driving, the shaft D being driven by the pinion and spur wheel E.

The next point was to reduce the speed on the driving wheel so as to give the engine sufficient leverage to get out of any

difficulty; and for this purpose two different driving speeds are provided, one giving $2\frac{1}{2}$ miles per hour and the other only 1 mile per hour for travelling, when the engine is working at its full speed of 140 revolutions per minute. In order to obtain sufficient adhesion under specially difficult circumstances for the exertion of the full tractive power of the engine, the additional provision has been made of temporarily fixing transverse T irons by means of bolts upon the rims of the wheels, as shown in Figs. 31 and 32, Plate 12. With regard to the men, time and experience combined with the extra work caused to them by getting into difficulties are the means of gradually reducing the difficulty arising from want of judgment on their part.

Another plan for meeting the difficulty of getting such heavy machines moved about has been adopted with the most satisfactory results. This consists in combining the power of two small-sized engines, as shown in Fig. 4, Plate 4, the second engine being worked in place of the moveable anchor in the previous plan of working shown in Fig. 3. Each engine is provided with a clip drum, which is essential to carrying out this system of cultivation; and the rope is worked as an endless rope between the two engines by having both its ends attached to the cultivating implement. As the power of both engines is applied at the same time to the rope in each direction, the heaviest class of operations can be performed by them; and the loss of power in working the rope is very much lessened by the fact that both lines of rope are always in effective tension, and are thereby well carried with half the number of rope porters. Another advantage derived from the adoption of this plan is that the engines are better adapted for the other work of the farm, as the farmer has then two engines of 7 or 8 horse power instead of one engine of 10 or 14 horse power; and by having two of them a regular system of cartage on the farm can be carried on, the engines being specially arranged for traction purposes.

IV.—The fourth difficulty to be surmounted was the production of a rope of sufficient strength and hardness, combined with

elasticity, to stand the required work; and this was a very serious point, as the inability to accomplish it nearly upset at one time the profitable employment of steam cultivation.

The first rope used was made of iron wire; but it was worn out so quickly, not doing so much as 200 acres, that it soon became evident such material would not stand the strain and friction attending the work; whilst by increasing the strength of the rope its weight was so much increased as to consume nearly the whole engine power in overcoming its friction. These difficulties became so serious that great exertions were made to get a rope of steel sufficiently hard to stand the wear of trailing on the ground and also the friction caused by coming in contact with the numerous pulleys of the machinery then employed; and in 1857 two steel ropes were applied which answered the purpose admirably, and performed with the then imperfect machinery upwards of three times the amount of work that was done by the first iron rope. From this point it was established undoubtedly that all risk of the difficulty with the rope causing a check to the application of steam to cultivation was now safely overcome, the introduction of the steel rope having effectually accomplished the object in view. The machinery for working the rope however required great improvement and alteration, before getting to the point of thorough efficiency with a minimum of wear: the chief objects in these improvements being to have as few bends as possible, and those bends over large pulleys. A great saving in the wear of rope has also been effected by the improved means of keeping the rope tight, preventing it from dragging upon the ground. From time to time, as the various improvements in the machinery have been effected, the increased quantity of work done by the rope before being worn out has been very marked; so that the cultivation of from 2000 to 4000 acres can now be accomplished with one steel rope, the amount varying with the nature of the soil and the width of the implement used.

Although much of this increase of duty depends upon the construction of the machinery, still a great part of the success is to be attributed to the superior manufacture of the steel wire. At

first the steel ropes, although much superior to those of iron wire, were very irregular in their quality and durability, often varying as much as one half in these respects; and up to the present day steel ropes made of the common qualities of steel wire vary in their quality to the same extent. After a series of careful experiments combined with accurate testing, a quality of wire has now been produced for the purpose, which can be obtained of complete uniformity in tensile strength, and possessing a high degree of hardness, combined with the requisite flexibility and toughness for working. To this great advance in the manufacture of steel wire rope is to be attributed in a great measure the present success of steam cultivation. The tensile strength of this wire has been increased from 1500 lbs. to in some cases 2400 lbs. for No. 14 wire gauge. Steel wire of the common sort has indeed been made to attain nearly the same tensile strength, but this is always accompanied by the defect of brittleness, which is a fatal defect in the working of a wire rope. If the quality of steel rope should continue to improve at the same rate as during the last three years, the cost of wire rope will be reduced to an unimportant item per acre.

At the commencement of steam cultivation the iron wire rope ran a mileage of not over 750 miles before being worn out, costing 1*s.* 7*d.* per mile of running. The first steel rope ran 1800 miles, costing 1*s.* per mile; and the present steel ropes are running on an average 9000 miles, costing only about $2\frac{1}{4}d.$ per mile, running with a tension upon them of about 25 cwts., and this notwithstanding that the price of rope has been increased from £60 to £84 for the ordinary length of rope of 800 yards. The steel rope at present used in steam cultivation is 11-16ths inch diameter, and weighs about 2 lbs. per yard, making a total of about 14 cwts. for the length of 800 yards.

V.—The fifth class of difficulties are those arising from variations in the state of the soil caused by the effects of the weather.

These difficulties have been principally felt in wet weather, in moving the engine, and also from the stickiness of some land when in a half wet state, which is too often the condition of the land whilst being cultivated. In such cases all the tackle would become

literally covered with clay, and the power required to move the rope and the machine would be very great. This difficulty should not indeed exist, as no land ought to be touched when in such a state; but clay land has hitherto very often been worked when wet, from want of sufficient force to get all the work done before the wet sets in, and also from the inability of horses to perform the work while the land is in a dry state. As an illustration may be taken a clay land field ploughed by horses while very wet, after which if the next year be dry it will be literally impossible to work the same ground with horses until some rain comes to soften it, as the horses' shoulders and the implement would not be able to stand such jarring work.

With steam power however there is no difficulty in working the land in the driest condition, which is the proper time for such work; and if this is strictly attended to, it will never get into an extremely hard state. Supposing the clay land is ploughed wet by steam power, more power will be expended in pulling the dirty rope and the sinking plough than even if the land be so dry that the soil breaks up into large pieces of as much as 1 cwt. each, though the latter could not be the case but for the wet-kneading that the land received before by being ploughed wet by horses. If the farmer were only to keep his machine off the land in wet weather, and work it night and day in dry weather, he would see the great advantage that would accrue from working at the proper time. In fact the principle of the old maxim, "make hay while the sun shines," applies to cultivation of the land as well as to hay.

Another system of steam cultivation has been adopted to meet special circumstances, by the use of two large engines, each of which is supplied with a winding drum, instead of the clip drum and endless rope employed with the light engines in the plan last described and shown in Fig. 4, Plate 4. The two large engines are placed at opposite ends of the field, the same as in Fig. 4, but they act alternately instead of in combination, one pulling the plough in one direction while the other moves forward into position for the return bout, and *vice versâ.*

In order to make the rope coil in a regular manner upon the winding drums of the engines, an arrangement of self-acting Coiling Gear is employed, which is shown in Figs. 33 and 34, Plate 13. It consists of a pair of guide rollers AA, between which the rope passes when coiling on or off the large winding drum B. These guide rollers are carried at the end of an arm C, which is centred at the other end upon a bracket D carried loosely upon the centre spindle E round which the drum revolves. The arm C has a stud fixed in it at F, working in a spiral groove G formed on the lower part of the spur wheel H, which also turns loosely round the centre spindle E. A second spur wheel I is carried close above the wheel H, and is fixed upon the upper end of a cylindrical casing carried up from the bracket D and passing through the wheel H. A pinion J carried by a stud fixed in the winding drum B gears into both the wheels H and I, but the upper wheel I has one tooth more than the lower one H; and consequently in each revolution of the winding drum the pinion J being also carried round with the drum causes the lower wheel H to be advanced one tooth, the upper wheel I being held stationary by the arm C, which is held at the outer end by the tight stretched rope passing through the guide rollers A. The spiral groove G is thus gradually turned round, and acting upon the stud F in the arm C causes this arm with its guide rollers A to be gradually raised and lowered, thereby guiding the rope from top to bottom of the drum in regular coils whilst it is being wound on or off the drum.

The purpose for which this system of working with two large engines was arranged was for travelling about and doing work by hire, so as to meet the requirements of those who have not sufficient land or capital to purchase machinery for their own use. The plan has the advantage of requiring no fixing, and the machines are ready to start work the moment they get into the field; and as soon as the implement stops, the ropes are in their places and the machines ready for removal. As fields of all shapes are met with, it is of importance that the machines should be of such a character that no loss of time should be occasioned by the management of the rope. So far as the working of these machines goes, it is entirely

satisfactory, but the first drawback to the adoption of this plan is the price. Secondly there is the difficulty of taking two large engines about; and from the fact that a heavy break has to be put on the paying-out drum in order to keep the rope tight, considerable power is lost. But still the time saved in doing small irregular fields more than counterbalances those disadvantages.

The traction part of the machinery having now been considered, the most mechanical means of performing steam cultivation has to be referred to.

The implements hitherto used for steam cultivation have been something similar to those employed with horse power; but recently a system has been arranged for throwing up the land in the roughest possible way, and leaving it in such a state as to expose the largest amount of surface to be acted on by the air, which is the only truly practical way of dealing with heavy land. The development of different classes of implements will always be going on, to meet different varieties of land and the various operations which will ultimately be required. It is proposed here only to refer to the best principle of loosening the land for the purposes of cultivation, looking at the question entirely from a mechanical point of view.

Cultivation by rotary implements has been much advocated, and may appear at the first glance the right means of applying steam power: but when the nature of the substance to be dealt with is considered, this plan is mechanically wrong in the way of operating on the soil, from the fact that rotary implements must necessarily strike on the top of the hard land, thus absorbing a quantity of power in entering the hard substance. As an illustration of this, reference may be made to the method adopted in breaking up a macadamised road: the pick is used so as to lever the material upwards, and by entering it underneath the hard substance the latter is easily broken up. A rotary digger must however be used in the contrary way, or else it will be acting against the onward motion of the machine, thereby increasing the power required for

traction. The difficulties that interfere with getting such a machine over the surface of the land have also to be considered, and the damage done to the land by the transit of such a heavy machine over the soil to be cultivated; and these objections, with the serious error in the mode of applying the power, must prevent such a system from proving practically successful.

The cultivation of the land consists merely in loosening a certain quantity of soil, and what has to be considered is how to loosen the greatest quantity with the smallest amount of power. In all the experiments tried by the writer it has been found that this is never so economically done as by wedging the soil off to a loose side, and entering the wedge underneath, where the soil is softer. Much objection has been raised to the old mode of working with the plough; but in the writer's opinion it is not the implement that is at fault in that case, but the power that is defective; and by the aid of steam that implement can now be driven at such a pace as to throw the land sideways in a manner quite equal to the effect of any digging by hand. The writer does not advocate any particular shape of mouldboards or tynes, nor the formation of a "furrow slice" as it is termed; all that is wished to be accomplished is to pitch the earth sideways, as in digging, and the shape of the tool must be such as to effect this in the best way. The great point requiring attention is that the tools should be so arranged that each follows its neighbour, taking its own cut and wedging off the soil to a loose side. If this is done, the speed of $2\frac{1}{2}$ miles per hour at which the implement is driven will throw the loosened material at least 2 feet clear from its previous position, and by the rapid motion it will be left in the state most desirable to the farmer and in the best possible condition to receive the action of the atmosphere, and this will be effected with the least amount of power. Few implements embody this principle; but without it there is a great loss of power, which is accounted for by the fact that a tyne or cutter in making its way through the solid ground always takes twice the power to draw it that would be required if it were taking its cut close to where another cut had been taken before. This is a point of great importance and should never be lost sight of in the

construction of implements for heavy work. In the implements for light operations it is by no means so necessary; but still the principle holds good to a certain extent and should be attended to as far as practicable.

In order that steam cultivation may be brought to the greatest perfection, it is of the utmost importance that the use of horses in cultivation should be altogether abandoned. For this purpose a number of implements are required, adapted to get over a large breadth of land in a day, so as to do the very light operations of the farm and exclude horses entirely from such work, as their use inevitably increases the expense of after operations, besides being detrimental to the land. If the horses on a farm are done away with altogether or as far as practicable, the cartage becomes the next question to be dealt with; and before steam cultivation takes its proper place, the heavy part of the cartage must be done by the ploughing engines. Considering however that to be good ploughing engines they must be good traction engines, there is nothing to stand in the way of cartage by steam power but the want of good roads about the farm, which are an essential point in a highly cultivated farm, whether steam cultivation be employed or not. The experience lately gained in the use of the traction engine is that loads can be conveyed over moderately good roads at an expense of 2*d.* per ton per mile; and there is therefore no doubt that the farm cartage can also be done economically. This operation will require some time to develop itself, as the vehicles for conveying the materials will have to be bought and proper roads made in every direction through the farm before steam cartage can be carried on conveniently; but at present there can be no reason why all corn should not be taken to market and coals and so forth brought back by steam power. The writer has no doubt that before ten years' time two thirds of the cartage of the farm will be generally done by steam, and also that the railways will be fed by traction engines, and that these will become quite common: although, through mistaken ideas, serious attempts have been made to stop their use on the public roads. A 10 horse engine will convey a load of 20 tons independent of itself over a road with

gradients not exceeding 1 in 15; and the wear and tear is very slight indeed in properly constructed traction engines.

In order properly to understand the advantages of steam cultivation, it is necessary to draw a contrast between steam power and horse power as applied to cultivation.

In the case of horses, the utmost available force which can possibly be brought to bear on an implement is 9 cwts., and this is obtained by employing six horses, or two more than can work profitably together on the land. The practical limit of draught is therefore 6 cwts., as horses cannot give off the same amount of draught in the fields as on hard roads. Hence with a team of four horses giving off 6 cwts. total draught on an implement which acts on a width of land of from 10 to 12 inches, the utmost total power per inch in width of the soil acted upon will be only 70 lbs. At the same time the resistance will be very much increased by the pressure of the horses' feet in doing the work. For if a horse be taken when the land is in a rather plastic state, and walked across the track of the steam plough and made to travel to and fro transversely on every 10 inches width until a breadth of 6 yards is trodden over, it is then found that, if the steam cultivator has just sufficient steam to perform its work properly before it arrives at the ground so trodden down, it will be completely stopped before it gets through the 6 yards; and considering the momentum of the flywheel, this experiment shows plainly that the power required is something very material, and experience shows one third additional draught to be required on land that has been trodden down to the same extent as in cultivation by horse power. It is clear therefore that a considerable part of the 6 cwts. draught of the horses is expended in undoing the compression caused by their own weight; and as the 4 tons weight of the horses themselves must be lifted up and down all the inequalities of the ground, there is only a very small portion of the animal force left to be usefully exerted upon the implement, and this only at the slow speed at which the horses travel of $1\frac{1}{2}$ miles per hour.

But with steam the case is very different: a draught of 35 cwts. is available upon the implement, giving the farmer the means of

employing a force of from 70 to 280 lbs. per inch in width of the soil moved. And considering that only $1\frac{1}{4}$ tons load is passing over the land instead of 4 tons, much less force is employed to move the same measurement of soil.

The comparison therefore stands thus:—with horses there is a total force of 6 cwts., with the drawback of having to convey 4 tons of useless load over the land; while with steam power there is a total force of 35 cwts. conveying only $1\frac{1}{4}$ tons of useless load. The result of experience is the less weight carried over the land the better; and when the great weight of horses compared with the force they exert is considered, and also the number of footprints left by them on an acre, it cannot but excite surprise that such an unmechanical means of cultivation should have existed so long. The number of footprints left by four horses in ploughing a 12 inch furrow is above 300,000 per acre; whereas the steam plough, which has a width of from 3 to 4 feet, is carried on two wheels 6 inches in width.

The facts that have been stated are surely a good reason why horses should be kept off the ground altogether. If the necessary precautions in this respect are but strictly followed, a complete revolution in agriculture will soon be witnessed, as no mechanical means of pulverising the land will be required, and less than one half the number of operations at present necessary will be found amply sufficient.

Looking at steam cultivation from an agricultural point of view, the question naturally arises why such an improvement should not become general at once. The advantages to the farmer who has met the requirements of steam by appropriate modifications in his farm and in his way of dealing with the land are very considerable: much greater indeed than the most sanguine could have anticipated. These advantages however, from the nature of the case, are but slowly seen, as reliable statistics of the actual results can be obtained only from a series of years. This consideration, together with the want of capital so much felt in agriculture, and the doubts as to the efficiency of steam cultivating machinery which the want of mechanical knowledge induces, leave little room for wonder at

the slow progress of its adoption. The cultivation of the soil is not an investment that yields quick returns; and with the present imperfect appliances it is also a very uncertain investment. Hence the farmer naturally pauses before he invests a larger sum than he has been accustomed to do in such permanent improvements on his farm as will enable him to get the maximum amount of work done in the proper season and at a minimum cost. Such further outlay on the farm must indeed be considered the business of the land owners; but although they will eventually be the principal gainers, few of them have at present given any assistance to the development of steam cultivation. Were they to take the matter up in such a way as an engineer would do, who had seen how he could effect a similar improvement in his mill or factory, the whole country would soon be seen covered with steam ploughs.

The gradual nature of the development of the machinery has also stood in the way of its immediate introduction. For as several persons using the first machine had a great deal of trouble from breakages, others were deterred from following their example, although they witnessed and acknowledged the improvements to the land and crops.

Land, like metal in a furnace, requires the greatest attention in order to perform the different operations at the time when it is in the right state for their being effected thoroughly. The present system of management is entirely inadequate to effect this object, from the want of sufficient force at a given time. In some years there are barely two months for all the cultivation of the season: that is, provided the greatest judgment is exercised, and the land never touched except when in the proper state for the purpose. But with such management as is recommended above, the result will be always an adequate crop.

The advantages of steam cultivation having now been described, and its gradual development during the past few years having been traced together with the various systems employed, it is proposed in conclusion to enumerate what may be considered as the

principal points which are essential to the production of good steam cultivating machinery, so far as regards its mechanical arrangements.

First, a sufficiently powerful engine with a wide bearing surface, and plenty of leverage to move itself out of difficult situations, and of simple construction in all its parts.

Second, a hauling apparatus with a drum of large diameter, and so arranged as to bend the rope as seldom as possible, and with the drum placed horizontally on a vertical axis so as to allow the rope to work in any direction without requiring guide pulleys.

Third, a direct pull upon the implement, with as short a length of rope as possible, and that of good quality, light, hard, tough, and flexible.

Fourth, an arrangement for keeping the rope tight, so as to carry it clear of the ground and avoid loss by friction.

Fifth, an implement in which the shares or tynes follow each other consecutively, wedging off the soil to a loose side.

Lastly, as small an amount of manual labour as practicable.

A few remarks only need be added upon the ultimate effect which will result from the proper adoption of steam cultivation. By thoroughly carrying out the system, definite calculation can be made as regards the cost of working a farm, and better crops will be obtained with a greatly increased amount of certainty. Time, the great point in all business, but more especially in agriculture, will be economised; and from the increased force at the farmer's disposal he will seldom get behindhand with his labour, an evil which at present often causes him to lose a crop altogether in some of his fields. The drainage will be much more efficient, and consequently the temperature of the land will always be kept at the highest point: the result will be that the land will always be in a growing state. Clay land, which is by far the most fit for crops, will be brought to bear the heaviest crops; and this quality of land, which at present pays very little rent, will become the most valuable. Farming will become a business into which a business man may enter with safety, and capital will find in farming a profitable and safe investment, so that increased advantages will accrue to the

country. The intelligence of the agricultural labourer will be improved, in consequence of his having to use his mind more and his body less; and this anticipation has received practical confirmation in not a few cases already.

Mr. Greig exhibited a working model of the clip drum, and a full size specimen of one of the pairs of clips, together with a sample of the steel wire rope at present used of 11-16ths inch diameter.

He explained that the difficulty of coming to a satisfactory conclusion regarding the relative value of the work done by steam cultivation as compared with horse cultivation arose from the different states of the land upon which the two methods were tried, the different operations to be performed, and the different situations in which the steam cultivators had to be placed. Taking these into consideration, the cost of steam cultivation was found to vary as much as from 2*s.* 6*d.* to 20*s.* per acre; and the expense of working a 14 horse engine, such as was now ordinarily employed for steam cultivation, would not come to more than £3 per day, including interest on the cost of the tackle and implements, allowance for depreciation, and wages; while the engine would work regularly up to the power of thirty ordinary horses. The cost on the other hand of farming with thirty horses, taking it at the very low estimate of only 3*s.* per horse per day and 1*s.* for attendance of men, or 4*s.* total for each horse, would amount to £6 per day, showing a clear saving of £3 per day by steam cultivation, independent of the superiority in the work done by the latter method. The great difficulty of making any calculations as to the cost of farming arose from the difficulty of correctly charging the different items to the different operations. Farmers making the

calculation of the charge of a horse generally fell into the mistake of reckoning it at only 2*s.* 6*d.* per day, forgetting that the horses worked on an average only 150 days in the year and were idle all the rest of the time; and on this account it was frequently difficult to show a farmer the advantages of steam cultivation.

Mr. J. Fernie remarked that the materials for the valuable paper that had been read had been in preparation by the late Mr. Fowler several months previously, and were left by him at the time when by an unfortunate accident he was so suddenly cut off from the engineering profession and the great agricultural interests which it was the work of his life to benefit. Though removed at the early age of thirty-eight, he had already accomplished a vast amount of work; beginning with the draining plough, he had gradually worked up the system of drainage and cultivation by steam power to the comparative perfection in which he left it, having succeeded in making it a commercial success. In the earlier years Mr. Fowler had been under the necessity of getting his various machines and tackle manufactured in different parts of the country, in order to be able to meet the demand for them; but at his death he left the present large establishment in Leeds, devoted entirely to the manufacture of steam cultivating machinery, employing as many as 700 men, and turning out the machines at the rate of nearly one a day, which were being sent to all parts of the world.

A very important improvement had been effected by the introduction of the clip drum, both in the application of steam power to cultivation and in other cases of communicating power by ropes; and the action of the clips and the great amount of grip which they exerted upon the rope were clearly illustrated in the model now exhibited, having a wire rope passing half round each of two pulleys, one of which was plain, while the other was a clip drum fitted with the clips all round its circumference. On holding the rope stationary by hand, the plain pulley was easily turned round by hand, with the rope slipping round it; but when this was attempted with the clip drum, it was found impossible to turn the drum, on account of the very tight grip with which the clips laid hold of the rope. The clip drum was now applied in other situations

besides hauling agricultural implements, such as for the winding pulleys at the summits of underground inclines in collieries, and in all cases he had observed that the drum was working horizontally; and he enquired whether it was ever employed in a vertical position, working on a horizontal axis, and whether the clips were found to answer equally well in that position.

The steam engines employed for working the various implements used for cultivation and drainage had not been referred to in detail in the paper; and one point deserving of particular notice was the general adoption of a steam jacket surrounding the cylinder, in consequence of which excellent indicator diagrams were obtained from the engines, showing that there was no condensation of steam in the cylinder. Before the use of the steam engine for agricultural purposes could become as extensive as was to be expected from its important advantages over the present sources of power, it was necessary that the restrictions at present imposed upon the use of traction engines on roads should be removed, and that the act of parliament at present in force on this subject should be modified or repealed; and he trusted all the members of the Institution would use their best efforts to attain this object, in the interest both of agricultural progress and mechanical engineering. According to the present act, traction engines were not allowed to pass along the common roads except between ten o'clock at night and six o'clock in the morning; but by taking proper precautions, and having men in front and behind, and shutting off the steam when a restive horse was passing, he was certain that all danger would be done away with. In reference to the condition in which the ground was left after ploughing with the steam plough, he enquired what was the nature of the subsequent further pulverising that had been mentioned in the paper, and whether it was similar to the clod-crushing and harrowing processes that were required after the ordinary ploughing with horses.

They were greatly indebted to Mr. Greig for the excellent manner in which he had completed the paper for the present meeting; and the mechanical details of the system of steam cultivation appeared now to have been so far perfected as to leave

little further to be desired in that respect. He hoped however that they would have the opportunity of hearing the opinions and ideas of those more immediately concerned in agricultural operations, that they might know in what light the system of steam cultivation described in the paper was regarded from a purely agricultural point of view.

Mr. Greig said that, in reference to the position of the clip drums, there were several of them successfully in use working vertically upon a horizontal axis; and when the clip drum was used vertically, it was best to pay on the rope at the bottom, because there the jaws were sure to be full open from their own weight in addition to the centrifugal force tending to keep them open. With regard to the question of further pulverising the ground after ploughing with the steam plough, he had watched very narrowly the working of the steam ploughs for several years past in connection with some very large farms, and was satisfied that, with proper management and where the steam plough was used in dry weather, there were no such things as clods after the ploughing, and no clod crushers would be required, except in special cases of very light soil, where it might be desired to consolidate the newly ploughed ground by passing the heavy roller or clod crusher over it. Harrows might indeed be desirable after ploughing with the steam plough, but only for the purpose of levelling the surface, as the earth did not require any further breaking up after the ploughing.

Mr. T. B. Wright considered the paper that had been read was a most interesting and valuable one, and he desired to express on behalf of the agricultural community in general the great admiration that was felt for the indomitable energy and unwearied exertions of the late Mr. Fowler in bringing steam cultivation into practical operation. This was one of the most important movements that had ever been originated and carried out in connection with agriculture; and at first the problem appeared so difficult, that it seemed very doubtful whether it would ever be successfully solved. Though it might still be doubted whether the best plan of steam cultivation had yet been hit upon, there could be no question that Mr. Fowler

had accomplished what the Royal Agricultural Society offered their prize for, by showing how it was possible to plough by steam; and the £500 prize offered by the Society for ploughing by steam was accordingly awarded to him at the Chester meeting in 1858. The particular implement indeed was of secondary importance compared with the power by which it was worked; and whether the plough would prove the most useful appliance for steam cultivation, or whether some other implement would ultimately be employed for the purpose, the motive power was the chief consideration; and it was upon this subject that the abilities of Mr. Fowler and his successors had been so advantageously exercised. All farmers would now admit that there could be no worse system than that of using the common plough drawn at a slow speed by several horses, whereby it was not possible to obtain anything like a proper seed bed; but all the disadvantages of the old system were escaped by the use of the steam cultivator. As to any further tillage or pulverising of land that had been ploughed by steam, he thought that generally nothing was necessary but the use of a light harrow, as in the case of the best hand ploughing, for levelling the surface of the ground after the steam plough, in order to leave a good seed bed. With regard to the wire ropes employed for drawing the cultivating implements by steam power, he remembered that the principal difficulty which had had to be encountered in using the iron wire ropes that were in the first instance adopted arose from the great weight of the rope itself and its rapid wear; and it might be mentioned that the first steel wire rope for the purpose had been produced in Birmingham by the late Mr. Webster, which was so superior in strength and lightness to the iron wire rope that when Mr. Fowler saw it he felt satisfied he had met with that which would enable him successfully to carry out his plans of steam cultivation.

The CHAIRMAN enquired what power the engine was indicating at the time of taking the indicator diagrams, and what amount of tractive force that would give upon the implement; and also whether the engines employed were single or double cylinder engines.

Mr. Greig replied that the indicated power of the engine was about 45 horse power, of which about 75 per cent. would be available at the implement, giving a tractive force of about 30 cwts. total upon the implement. Single cylinder engines were now being made for agricultural purposes, because they were much more simple in all their parts, whilst they were capable of doing the same work as double cylinder engines, and were cheaper in first cost; and he believed that before long the double cylinders would be altogether abandoned for agricultural engines. With double cylinders there was frequently a deficiency of steam in engines of only 12 or 14 horse power nominal, and the friction of the double quantity of mechanism was a serious loss upon the power of such small engines. The only difficulty that arose with a single cylinder engine was in the management of the reversing gear, and at first there was a serious loss of time in starting, whenever the engine happened to have stopped upon the centre. This was now entirely got over however, and there was no longer any trouble in that respect, the only thing necessary being a little judgment on the part of the engine driver, who set the engine going with a small quantity of steam, before starting the implement, so that it was just running slowly; and then by a simultaneous movement of the two handles the clutch was thrown into gear for starting the implement and the full steam admitted to the cylinder at the same instant, when the crank was about at its position of maximum power. In this way all difficulty from the use of a single cylinder was obviated. Mention had been made of steel wire ropes as having been made first in Birmingham, and that was the fact, and the first steel wire rope made there had proved a very valuable one and continued still in use at the present time; but the best steel wire ropes were now however obtained elsewhere, and he hoped the Birmingham manufacturers would take the matter up and recover their original position as makers of the best steel wire ropes.

Mr. E. E. Hewett enquired what were found to be the results of the system of cultivation described in the paper as compared with the plan of direct traction, in which the engine travelled over the land and drew the cultivating implements after it. He understood that at

the comparative trial of the two methods at Chester in 1858 it had been found that the traction engine travelling over the ground did twice as much work when working up to the same power as the stationary engine pulling the implement by a wire rope from the headland.

Mr. Greig replied that several attempts had been made to perform steam cultivation by means of a travelling engine drawing the implement after it, but they had in all cases been ultimately abandoned as altogether impracticable. The effect upon the crops was decidedly injurious, as the wheel marks of the traction engine were plainly visible throughout the field in the following harvest, by the crop not being so good and having a burnt appearance in the parts where the wheels had passed and compressed the soil, particularly if the ground had been at all wet at the time of the engine travelling over it. At the same time the consumption of coal to do the same work was at least twice what it would be in a stationary engine working by ropes, as the travelling engine had to convey its own weight over the ground in addition to drawing the implement. In the comparative trial at Chester he believed that, though both engines were nominally of the same power, the traction engine was working at more than double the power of the stationary engine; and although the former was in consequence accomplishing apparently double the work, as estimated by the number and depth of the furrows, yet the work was not performed so efficiently and the ground was not left in such good condition as with the plough drawn by a wire rope from the stationary engine, on the system described in the paper. He was not prepared to maintain that the best method of steam cultivation had yet been arrived at, but there was no question that it had already been brought to a condition of practical efficiency and commercial profit, so as to be worth while to any farmer to take it up; and no doubt there would continually be further improvements in future years, particularly in the implements used, which must be considered to be at present altogether in their infancy. The number of different implements made use of was itself sufficient to suggest that there was ample room for improvement; and he did not see why the three operations

of ploughing sowing and harrowing should not ultimately be carried out at the same time by employing only a single implement for the purpose. One misconception in regard to steam cultivation arose from using the same word to describe the operation of ploughing, whether done by horses or by steam power; whereas the effect produced by steam ploughing was so entirely different as to give it the character of a distinct operation. With the horse plough the soil was simply turned over in a slice, leaving a distinct furrow; but with the steam plough it was either thrown straight up in the air, or thrown sideways to a considerable distance, or broken and turned up from below, according to the shape and arrangement of the shares and mouldboards and the speed at which the implement was driven, and no furrow marks were visible after the process. These different varieties of the operation were severally employed according to the nature of the land to be cultivated, nor did he think that any single process would be applicable successfully to all descriptions of land alike, but the action of the cultivating implement must be varied in every case according to the quality of the land.

Mr. John Smith remembered seeing the comparative trial at Chester in 1858 that had been referred to, and he thought the traction engine which drew the implement after it had not on that occasion really accomplished so much as an acre of work during the whole time of the trial, and there was a great deal of trouble with it in turning at the ends of the field; also in that case the work done was of inferior character, as the implement only rucked up the soil, without turning it over at all. From the results obtained in the crops produced he was satisfied that the system of steam cultivation described in the paper had everything to recommend it. A farmer whom he knew in the neighbourhood of Wolverhampton had adopted a set of Mr. Fowler's tackle and implements several years ago, which had proved completely successful, notwithstanding that it was one of the earlier arrangements involving the trouble and inconvenience of the three drums under the engine and a number of guide pulleys for the rope to pass round in the field. One of the fields so ploughed about five years ago, which had previously been very deficient in its crops,

had never failed to yield a good crop since, and appeared likely to continue equally productive for years to come. It was a field that threw up a great deal of coltsfoot and dock, and had therefore been ploughed as much as 12 inches deep, since which there had never been any trouble at all with those weeds.

The CHAIRMAN enquired whether steam cultivation was resorted to in foreign countries for any other purposes than those known in England.

Mr. GREIG replied that a considerable number of the steam ploughs had been sent out to sugar plantations, and most favourable accounts had been received of their working. It was found that a sugar plantation of about a hundred acres would pay for a steam plough with engine and tackle complete by the difference in the crop of sugar produced in a single year; and this was a most satisfactory and decisive result in favour of the steam plough. In Cuba, owing to the very dry season last year, there had been scarcely any sugar crop at all except where the steam plough had been used; and the explanation of the difference he believed to be that by means of steam power the land was ploughed before the dry weather set in, and consequently retained sufficient moisture during the whole season. There were also a considerable number of the steam ploughs in Egypt, some on sugar plantations, but the greater part employed in the cultivation of cotton; the great stimulus given to the growth of cotton and the dearth of animal labour had necessitated the employment of steam power in Egypt. Steam ploughing was also being done on the land recovered by the drainage of Haarlem lake; and in that case, owing to the very soft nature of the soil, the wheels were made 2 ft. 6 ins. broad, in the manner shown in the drawing, for obtaining sufficient width of bearing surface on the ground.

The CHAIRMAN enquired whether the steam draining plough was still in use, as described by Mr. Fowler in his former paper in 1857, and whether any material alterations had been made in the operation.

Mr. GREIG replied that the draining ploughs had been used considerably in Essex, and there were at present ten of them in different parts of that county, which were constantly in use,

answering both practically and commercially, and earning a considerable sum, as they were let out extensively for hire to the farmers in the district. The use of drain pipes was now abandoned in clay land, as it was found that the simple hole bored by the draining plough was all that was required; the only difficulty was where the soil happened to change in character along the course of the drain, because in a sandy soil the drain might drop in; but in clay land there was no difficulty whatever from that cause. The drains were bored at about 3 feet depth and about 16 feet apart; the holes might be bored any size, but generally it was found best to make them about 4 or 5 inches diameter. At one time about 150 acres of land at Hainault had to be drained with drains 4 feet deep by means of the steam draining plough; but it was afterwards found that that depth was too great, as the water could not penetrate into the drains owing to the great compression of the clay at such a depth. Down to about 3 feet or 3½ feet depth however the drains were found to answer very well in the clay land.

Mr. E. T. Bellhouse enquired, in reference to the use of a single-cylinder steam engine for ploughing, whether such an engine was suitable also as a traction engine; because he did not think any system of steam cultivation would be complete, unless the engine were capable of transporting itself from one place to another together with the implements and tackle. An engine was therefore required that would both work the plough and serve as a traction engine; and there were so many difficulties in getting over the ground where the roads were bad that nothing but an engine of the strongest character would be able to do the work it would meet with.

Mr. Greig considered a single cylinder engine was the best for a traction engine, and he had found no difficulty in the working of such engines. That was evidently the opinion also of one of the principal makers of traction engines, who made none but single cylinder engines for the purpose. As to the ploughing engine being used for a traction engine, it had as a ploughing engine to overcome difficulties that a traction engine seldom encountered, and therefore any engine that was a good ploughing engine must be

strong enough to be a good traction engine also. Their present practice in the construction of the single cylinder engines was to place three quarters of the weight upon the driving wheels to be available for traction, leaving only one quarter on the front wheels to steer by. At first it had been feared to put the machines to work upon stony lands, lest large stones should damage the implements and put too great a strain upon the engine. This fear proved however to be without foundation, and in one case that he had witnessed a machine put to work on very stony land was tearing up stones as large as 4 feet long by 2 feet wide and 1 foot thick, and tearing up no less than 20 tons of stone per acre: the machine did 70 acres of that sort of work, and came back with only two tynes bent in the cultivator. Such results far surpassed all previous expectations as to the capabilities of steam cultivating machinery.

The Chairman enquired whether both the driving wheels of the engines were driven by the power, and how the steering was managed with the very broad wheels that had been alluded to.

Mr. Greig explained that each driving wheel was driven by a friction clutch keyed upon the driving axle, and the friction clutch on one side was screwed up tight, while that on the other side was only half tight, so as to allow of slipping in turning; or in a sharp turn one friction clutch was slackened altogether, allowing the wheel on that side to run loose on the axle. By this means the engine was turned readily, whatever might be the width of its driving wheels.

The Chairman enquired what was generally the expense of steam cultivation, and the absolute cost of the machinery and the repairs.

Mr. Greig replied that a 14 horse power engine with implements and tackle complete might be reckoned at less than £1000, the actual cost being about £944. There were two implements supplied with each engine, of different construction, a cultivator with seven shares and a plough with four; the cultivator was for going over the land previously ploughed, and its shares or tynes had only a cutting action without turning the soil over. The total cost of repairs, to allow for renewal of the whole, might be taken safely at 15 per

cent. on the outlay, being 10 per cent. for the working repairs and 5 per cent. interest. For working the engine and implements two men and three boys were required, making the cost for labour about 10*s.* per day. In case of having two engines, one at each end of the field, three men and two boys would be employed, and the two engines of 7 horse power in place of one of 14 horse power would raise the total cost to about £1140.

The Chairman enquired whether accidents to the machinery were of frequent occurrence or whether the expense of repairs arose from the mere wear and tear of the engines and machinery. It appeared that very little trouble was experienced from the large stones sometimes met with, and he enquired whether the repairs of the rope formed any considerable item in the expense.

Mr. Greig replied that the repairs were merely those arising from regular wear and tear, and accidents of any sort seldom occurred. The steel wire ropes were now made so strong that they seldom broke on less than 1000 acres, and 2000 acres were now often done before any breakage took place. There was indeed no fear of breaking the rope; for if the implement caught against a stone the rope would stop the engine dead before it would break; and the cost of maintenance of the rope was the merely nominal sum of only about 6*d.* per acre.

Mr. E. E. Hewett enquired whether the steam plough was able to plough the whole of the field, or whether a second plough had to be used to finish the headlands afterwards, and what percentage was generally left unploughed.

Mr. Greig explained that each field was completed by the steam plough itself, the headlands being left unploughed; and on that account it was not profitable to take the steam plough into small fields, say only 7 acres: such small fields indeed should not exist at all for steam cultivation, and it was found that the steam ploughs were never purchased for farms that were cut up into small fields. In large fields of 20 or 30 acres the land left unploughed would probably not be more than half an acre, unless there were very crooked fences which would prevent the engine and implements from being worked in favourable positions. If it were desired in

any field to plough the headlands also, it would be better to plough them by horses, in order to save the time and labour of readjusting the engine and tackle for such an insignificant amount of work.

Mr. W. Richardson asked whether the engines would work best far asunder or close together, supposing the steam plough were working in an unenclosed country like Egypt or South America where the ground could be laid out in any way that was found best.

Mr. Greig considered the most profitable mode of working was to have the two headlands about 300 or 400 yards apart. Sometimes fields had been met with where the headlands were 500 yards apart, but that distance took all the strength of the rope to do it. When the distance apart was increased beyond the ordinary run, the increased wear and tear of the rope more than counterbalanced the time saved in turning; so that in the case of a width of 600 yards it would be better to plough it in two widths of 300 yards each, because there would be less wear and tear. On the other hand in small fields there would be a considerable time lost in turning at each headland.

The Chairman remarked that the paper had shown clearly the successive stages by which the present system of steam cultivation had been arrived at; and he had himself had an opportunity of seeing the steam plough at work two or three years ago, both on the second plan described in the paper, with the stationary engine in the middle of one headland and the rope led round anchor pulleys at the opposite sides of the field, and also on the improved system of direct pull, getting rid of many of the bends in the rope, which was now carried out with so much success. It was clear now, from the experience previously gained, that there had been two very important objects to be attained: the one to get rid of as much weight in the rope as possible, by making the rope itself as small as possible; and the other to make the bends in the rope easy and few in number, and reduce the wear and tear on the rope in driving. The former of these objects had been accomplished by the use of steel instead of iron wire in the manufacture of the rope; and the latter by the clip drum, which was certainly a most ingenious and valuable contrivance, and had been found to work

with the greatest success and regularity. He had seen the clip drum in use in the horizontal position shown in the drawings, in which it was employed in steam cultivation, and had been much struck by the boldness of the method of adjusting the distance between the upper and lower row of clips, so as to adjust the whole set simultaneously by a single turn, by the simple expedient of chasing a screw thread upon a drum of even 7 feet diameter, instead of employing a separate adjustment for each pair of clips, which might at first sight have seemed the only way to effect the object; and the screw was found to answer the purpose in the most thoroughly satisfactory manner. The contrivances for taking up the slack of the rope so as to keep it clear off the ground were also particularly deserving of notice, from their simplicity and practical efficiency in accomplishing what was evidently a point of much importance to the success of the system. The slack gear on the plough itself ensured the rope being drawn tight by an entirely self-acting apparatus before the plough started in either direction, and the action was reversed simply by the ploughman taking his seat at one end of the implement or the other. The compensating break attached to the winding drum also served to prevent the rope becoming slack, the rope being drawn off under the constant tension kept upon it by the friction of the break.

He had no doubt that the time was coming when the use of engines upon common roads would be a necessity, and that horses would soon become accustomed to the passage of a steam engine; and if at first they were frightened it was very easy to stop the engine. But the use of engines on common roads ought not to be prohibited merely on account of frightening horses, any more than soldiers were prevented from marching through the streets because horses would take fright at the sound of the drum. He remembered travelling frequently by Hancock's steam carriage, which used to run regularly twenty-five years ago through the streets of London from the Bank to Paddington, at a speed of 7 or 8 miles an hour or even 10 to 12 miles an hour on good parts of the road. At first the horses were certainly much frightened at it, but when it had been running a month the omnibus horses took no notice of it at all.

He was sure all the members must feel greatly indebted for the full and able paper that had been read; and while they deeply regretted the early loss of so eminently practical and energetic a member of the engineering profession as the late Mr. Fowler, there was no reason to doubt that the work he had so admirably begun would be ably carried on by his successors.

He proposed a vote of thanks to Mr. Greig for the paper, which was passed.

The following paper, communicated through Mr. Walter May of Birmingham, was then read:—

DESCRIPTION OF A HIGH-SPEED COMPRESSED-AIR HAMMER, FOR PLANISHING, STAMPING, FORGING, &c.

By Mr. WILLIAM D. GRIMSHAW, of Birmingham.

The objects of this Compressed Air Hammer are to obtain a self-acting hammer with a great range in the force and rapidity of the blows, so as to be suitable for light forging, tilting, and planishing; or capable of being worked by hand with heavy blows for stamping when required; and also arranged to be driven by a belt from a shaft, in order to be applicable where direct steam power is not available. The machine consists of a force pump supplying compressed air to a reservoir, and a working cylinder and piston with hammer similar to those of a steam hammer, but worked with compressed air instead of steam, and having arrangements for varying the action of the hammer as required, and increasing the rapidity of the blows considerably beyond the speed of revolution of the driving pulley.

The hammer is shown in Figs. 1 to 6, Plates 14, 15, and 16. Fig. 1 is a side elevation of the hammer, partly in section; Figs. 2 and 3 are front and back elevations; and Fig. 4 is a plan, partly in section.

The double-acting air pump A, Fig. 1, is 8 inches diameter and 8 inches stroke, and is worked by a crank pin on the driving pulley B; it has a solid piston fitted with cupped leathers, and cast iron suction and delivery valves C, which are circular with flat faces, and each fitted with a light spring on the top to close the valve promptly. The interior of the hammer frame D forms the reservoir, into which the compressed air is delivered by the pump, and the pressure is regulated by the safety valve E, with a sliding weight or spring balance to alter the working pressure of the

hammer. The piston F of the hammer cylinder is $4\frac{1}{2}$ inches diameter, packed with cupped leathers, and has a full stroke of 10 inches. The compressed air is admitted below and above the piston alternately by the slide valve G at the top of the cylinder, and escapes by an exhaust port at the side of the cylinder H. The pressure of the air admitted to the cylinder from the reservoir D is regulated by the throttle valve I, worked by the foot treadle K; the throttle valve spindle is seen in Fig. 5, which is a horizontal section through the hammer cylinder.

The slide valve G is of cast iron, and is shown separately to a larger scale in different positions in Figs. 7 to 11. It is faced both back and front, with the ports passing through to the back; and two adjustable cut-off slides J J are placed on the back for altering the points of cutting off the air. These are regulated separately by screws L L, which pass through the side of the valve-box, and serve to hold the cut-off slides stationary in any desired positions.

The slide valve G is worked by a crank pin on the horizontal disc M, Figs. 1, 4, and 6, and this is driven by contact with the vertical wheel N upon the shaft of the driving pulley B; the disc M is pressed down by a spiral spring O upon the lower end of its spindle, as shown in the section Fig. 6, and the vertical wheel N is faced with leather on the edge, to give the required adhesion for driving it. This wheel N slides along the driving shaft upon a feather, and is shifted by the lever P, varying the speed of driving the disc M by acting upon it at different distances from its centre, and thereby giving a range of speed for driving the slide valve up to more than double the rate of revolution of the main driving pulley B. By means of the lever P, which is held in a series of notches, the number of blows of the hammer can thus be changed, without stopping it, from 150 up to 420 per minute, with the usual working speed of from 150 to 200 revolutions per minute of the driving pulley.

The valve spindle is connected with the crank pin on the driving disc M by a connecting rod R having a forked end, as shown in the plan, Fig. 4; and this can be at once disconnected by withdrawing the fork R by means of the handle S. The slide valve is then

worked by hand or foot by means of the lever T, when the hammer is required to be used for stamping; and the lever T is removed by drawing it out of its socket when the hammer is required to be worked self-acting.

An efficient hammer worked by compressed air is found very advantageous in many situations, such as where there would be material loss of power by condensation in bringing steam from a great distance, or where the damp from leakage of steam or the dropping of condensed water on the anvil would be objectionable, as in shops where bright steel is exposed or where the planishing of bright work is carried on. The air hammer also meets the cases where horse power or other power than steam is alone available; and it has an advantage in being always ready for work, not having any accumulation of condensed water in the cylinder and passages as in the steam hammer. There is also a saving in lubrication and in wear of the working parts, from their not being exposed to the heat of high pressure steam.

In this air hammer the force, rapidity, and quality of the blow can be changed with great promptness and accuracy. The force of the blow is regulated by shifting the safety valve weight E, or by means of the throttle valve I altering the pressure of air upon the top of the hammer piston; and the slide-valve motion admits of altering the rapidity of the blow instantaneously, giving also the means of obtaining a very high speed without involving any destructive tappet action, as the small slide valve G is alone required to be worked at the high speed. The arrangement of the cut-off slides J gives the means of regulating the quality of the blow, from a full stamping blow, to a sharp pick-up blow striking with any degree of lightness and well suited for such work as planishing and shaping hollow ware; and by the use of the hand or foot lever T the hammer is readily and conveniently worked as a simple stamp.

A working model of the hammer was exhibited, and shown in action.

The Chairman enquired where any of the hammers were in use, and what work they were employed upon.

Mr. Grimshaw replied that several of the hammers were now in use in Birmingham and the neighbourhood, employed for various stamping and forging purposes; also one at Glasgow for coppersmith's work, shaping and planishing vacuum pans for sugar refining, and one at Sheffield for steel tilting. The pressure of the air could be varied by altering the load on the safety valve, and the hammers had been worked at pressures from 7 to 30 lbs. per square inch; the ordinary pressure at which they were worked was about 20 lbs. per square inch.

Mr. E. T. Bellhouse enquired whether the hammer had been used for forging iron, as in a smith's shop; and whether in stamping plate iron it had been tried stamping the metal cold.

Mr. Grimshaw replied that one of the hammers had been at work for more than seven months in a smith's shop for ordinary forging work; and in that case it was employed also for blowing the fire in the intervals while the iron was being heated, by a connecting pipe being carried to the tuyere from the air reservoir. In stamping plate iron the hammer could be used for stamping the metal either hot or cold as might be desired.

The Chairman asked what was the greatest number of blows per minute that had been obtained with the hammer.

Mr. Grimshaw replied that the greatest speed at which the hammer had been worked was 800 strokes per minute, and it could be driven at any number of blows below that amount. It was usually worked self-acting for any speed above 100 blows per minute, but below this it was generally preferred to throw the self-acting motion out of gear and work it by hand; or in case the workman wanted both his hands free, the treadle gave the means of working the hammer by foot.

Mr. W. Richardson enquired what was the size and cost of the largest hammer that had been put to work yet, and what pressure of air it was worked at.

Mr. Grimshaw replied that the largest of the hammers yet put to work had a cylinder $8\frac{1}{2}$ inches diameter and a stroke of 28 inches; he did not know what pressure it was working at, but the pressure might be adjusted to any amount from 5 lbs. up to 40 lbs. per square inch. The cost of such a hammer was about £180, and of a hammer of the size shown in the drawings about £50, the larger hammer requiring about 5 horse power to drive it, and the smaller about 1 horse power.

Mr. E. H. Carbutt thought the air hammer was not as suitable for steel tilting, and would not be able to compete with the steam hammer for that purpose, since its power was not to be compared with that of the steam hammer. The greatest advantage of the air hammer he considered would be for stamping small articles, in place of hand labour.

The Chairman enquired what was the greatest speed of blows that was obtained by the steam hammer.

Mr. E. H. Carbutt said that several steam hammers of from 4 cwts. to 10 cwts. were working in Sheffield, with which 500 to 600 blows per minute could be struck if required; and they were regularly working at 300 blows.

Mr. Grimshaw observed that in reference to tilting steel there was one of the air hammers now at work in Birmingham which was employed in drawing down steel; a bar of steel 4 inches long and $\frac{5}{8}$ inch square was drawn down to a length of 14 or 15 inches with a regular taper, and 36 of these were produced by the hammer in 19 minutes in the ordinary work, which he believed it would be impossible to accomplish by any steam hammer at present employed. The average speed of the air hammer for that work was about 340 blows per minute in regular working, and that was as fast as the man could turn his hand for turning over the mould between each blow; the speed could however be increased whenever desired up to 600 or even 800 blows per minute. When the drawing of the steel was finished, the hammer could be stopped instantly, with a promptness which could not be attained with the steam hammer.

Mr. W. Richardson thought all that had been performed by the air hammer in steel drawing and other work could be accomplished equally well by ordinary steam hammers, as regarded both the rapidity and force of the blows. The main advantage he considered to be gained by the use of the air hammer would be preserving the die always dry and free from liability to droppings of condensed steam; there were many kinds of work in which a dry die was a matter of great importance, and for such cases the air hammer appeared admirably adapted; but for general work he did not think it could compete with the steam hammer.

Mr. Grimshaw mentioned that the steam hammer had been abandoned for steel tilting at some of the works in Sheffield, and the air hammer adopted instead, as it was found preferable for the purpose. At Messrs. Sanderson's works one of the air hammers had been at work for a considerable time for bolstering and forging knife blades &c.; and at another steel works a shop was going to be built to contain six of the air hammers.

Mr. C. H. Adames said that he used to employ steam hammers for planishing hollow ware at his works in Birmingham, but had been obliged to abandon them for bright iron work, on account of the droppings and moisture from the steam; and he had now put up for the purpose one of the air hammers described in the paper, which had been at work for ten months and had proved very successful and had shown he considered a decided economy as compared with steam. He accordingly intended to remove two steam stamps of large size at present in use, and replace them by air hammers, which he was satisfied would answer well.

The Chairman remembered an air hammer being made by the late Mr. John Hague about thirty-five years ago, which he believed was one of the earliest air hammers that had been made. It was worked as a vacuum hammer, by exhausting the air, instead of by compressed air, and was constructed for the purpose of planishing frying pans; and it worked with such an extraordinary rapidity that it was impossible to see where the hammer was in working, and the effect seemed more like giving one continuous pressure. That hammer was however wanting in the elegant contrivance for

regulating the blows that was shown in the hammer now described; and he was particularly pleased with the mode of working the slide valve by the neat arrangement of the friction wheel and disc running in contact with each other. He enquired how the surfaces of the wheel and disc had been found to stand in work, and whether there was much liability of their slipping; and what amount of repairs had been required to any of the hammers.

Mr. Grimshaw replied that in the first of these hammers that was put to work the surfaces of the friction wheel and disc for working the slide valve were merely iron against iron, and worked in that condition for seven months with only an occasional slipping when a little oil from the bearings happened to get upon the surface of the disc. Afterwards the bearing of the disc had been recessed, and formed into an inverted cup, to prevent any risk of oil getting upon the rolling surface; and the friction wheel had been faced with leather to increase its hold upon the disc and diminish the wear. No repairs had yet been required to any of the hammers at present at work, and the only accident that had occurred to any of them had been that the cylinder bottom got broken through an accident in the first hammer, which had been put up mainly with a view to testing the cost of working and the actual wear and tear of the several parts.

The Chairman moved a vote of thanks to Mr. Grimshaw for his paper, which was passed.

The Meeting then terminated.

BREAKING ROLLERS AND SCUTCHING MACHINE.

Fig. 1. *Breaking Rollers.*

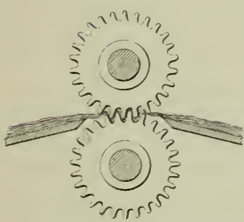


Fig. 2. *Scutching Cylinder.*

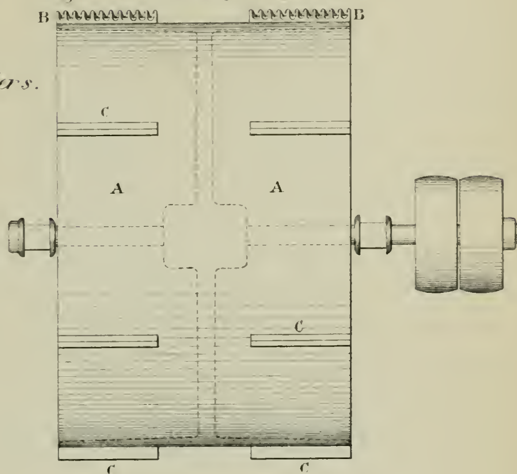
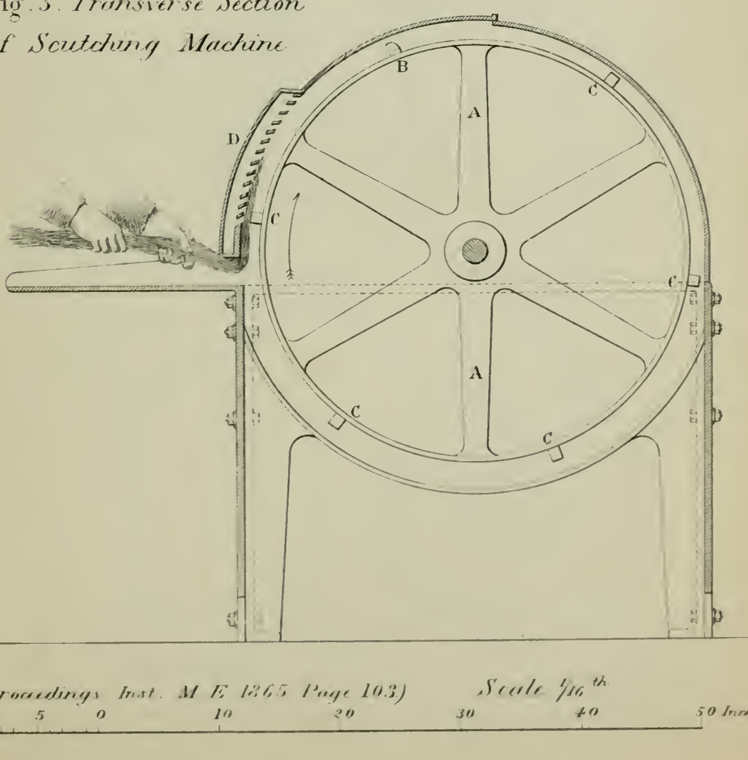


Fig. 3. *Transverse Section of Scutching Machine.*

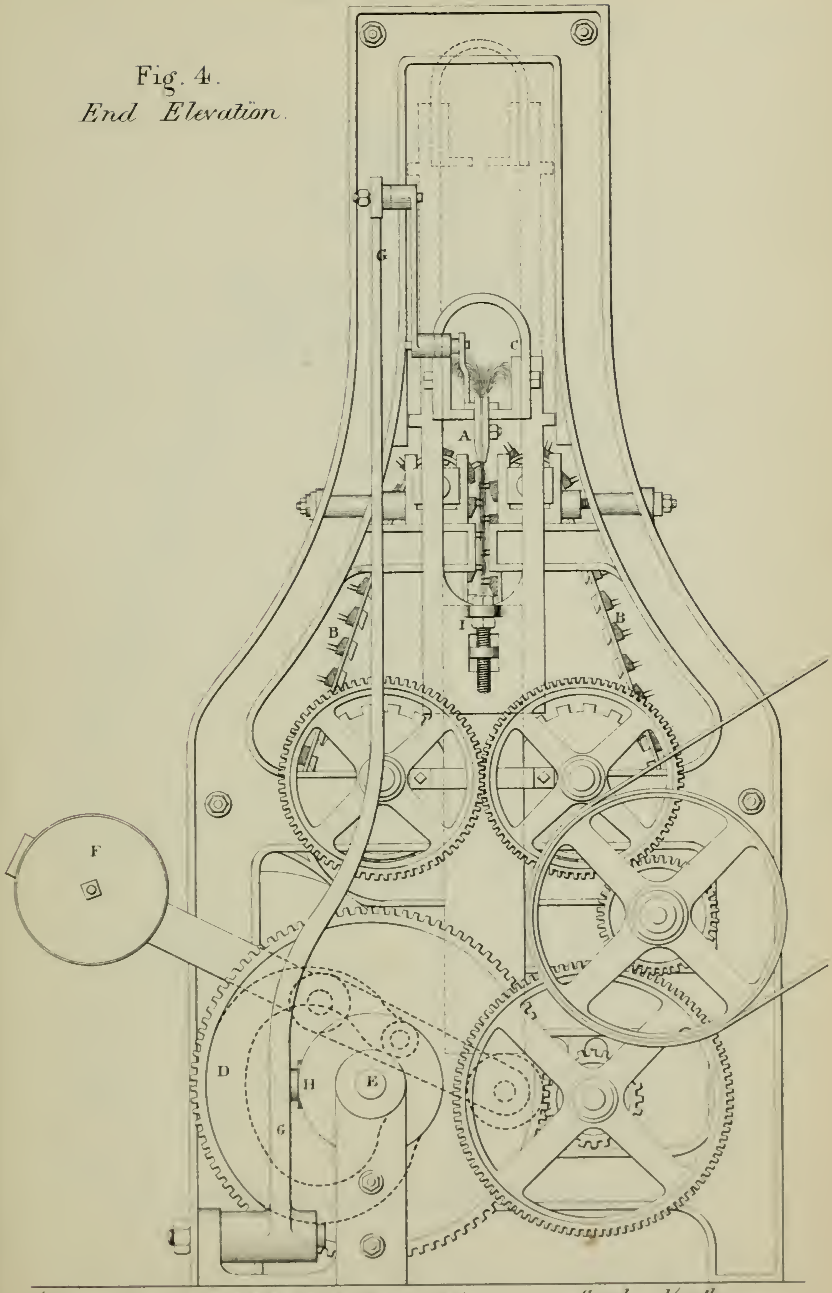


(Proceedings Inst. M. E. 1865 Page 103) *Scale 1/16th*

10 5 0 10 20 30 40 50 *Inches*

HECKLING MACHINE.

Fig. 4.
End Elevation.



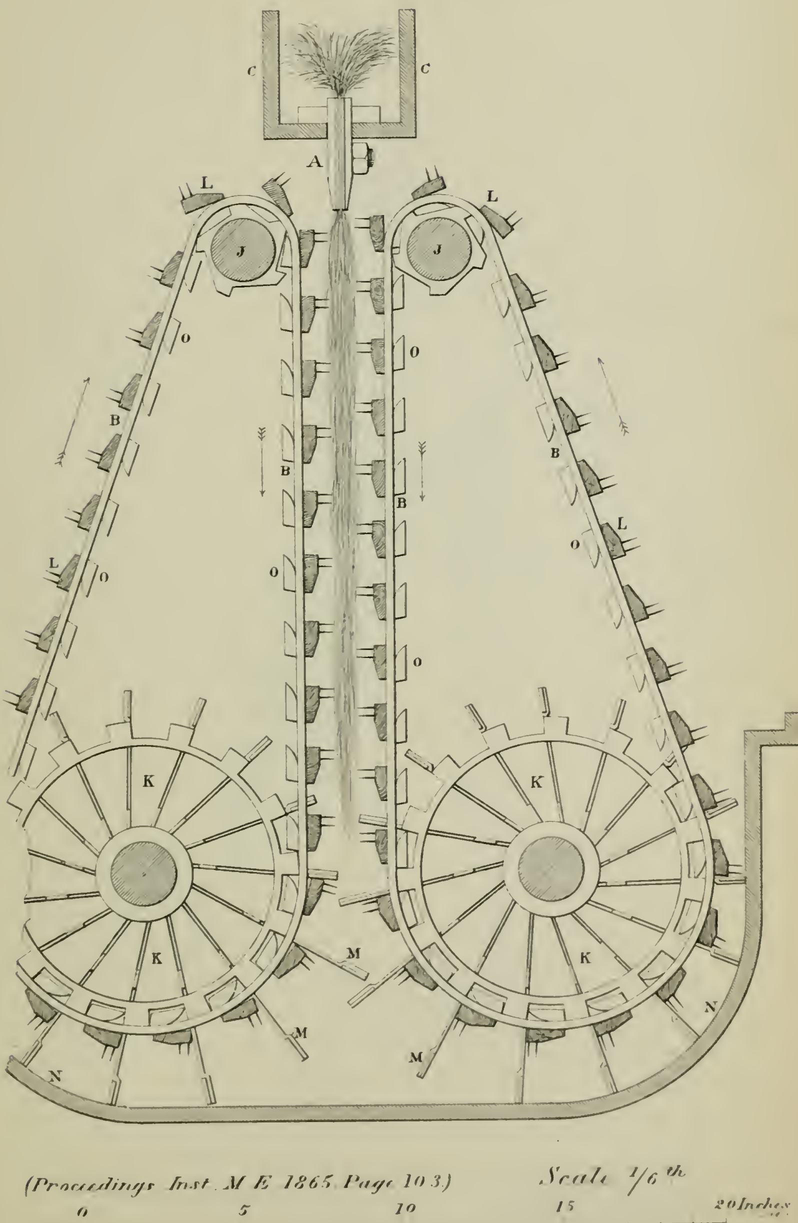
(Proceedings Inst. M. E. 1865. Page 103.)

Scale 1/12 th

10 5 0 10 20 30 Inches

HECKLING MACHINE.

Fig. 5. *Transverse Section through Heckles, enlarged.*



(Proceedings Inst. M E 1865 Page 103.)

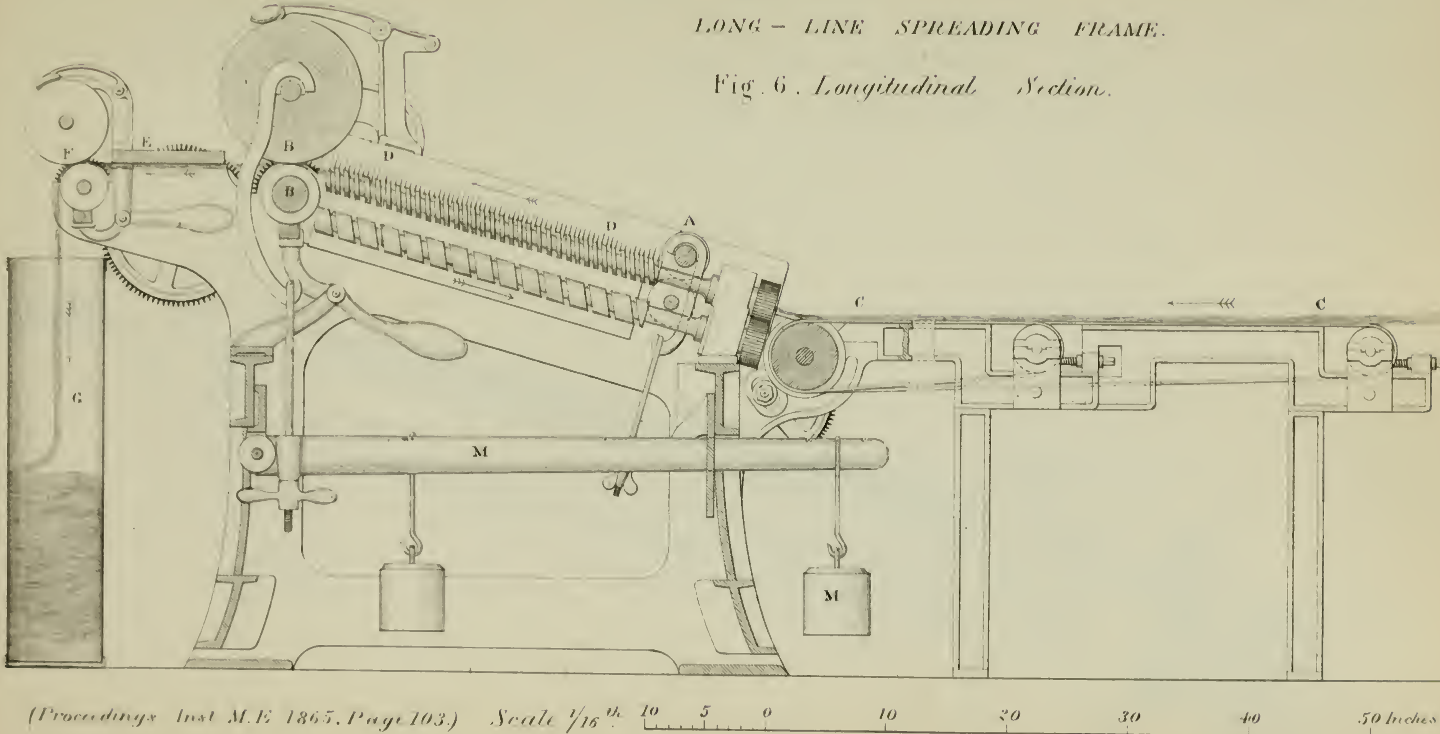
Scale 1/6th

0 5 10 15 20 Inches

FLAX MACHINERY.

LONG - LINE SPREADING FRAME.

Fig. 6. *Longitudinal Section.*

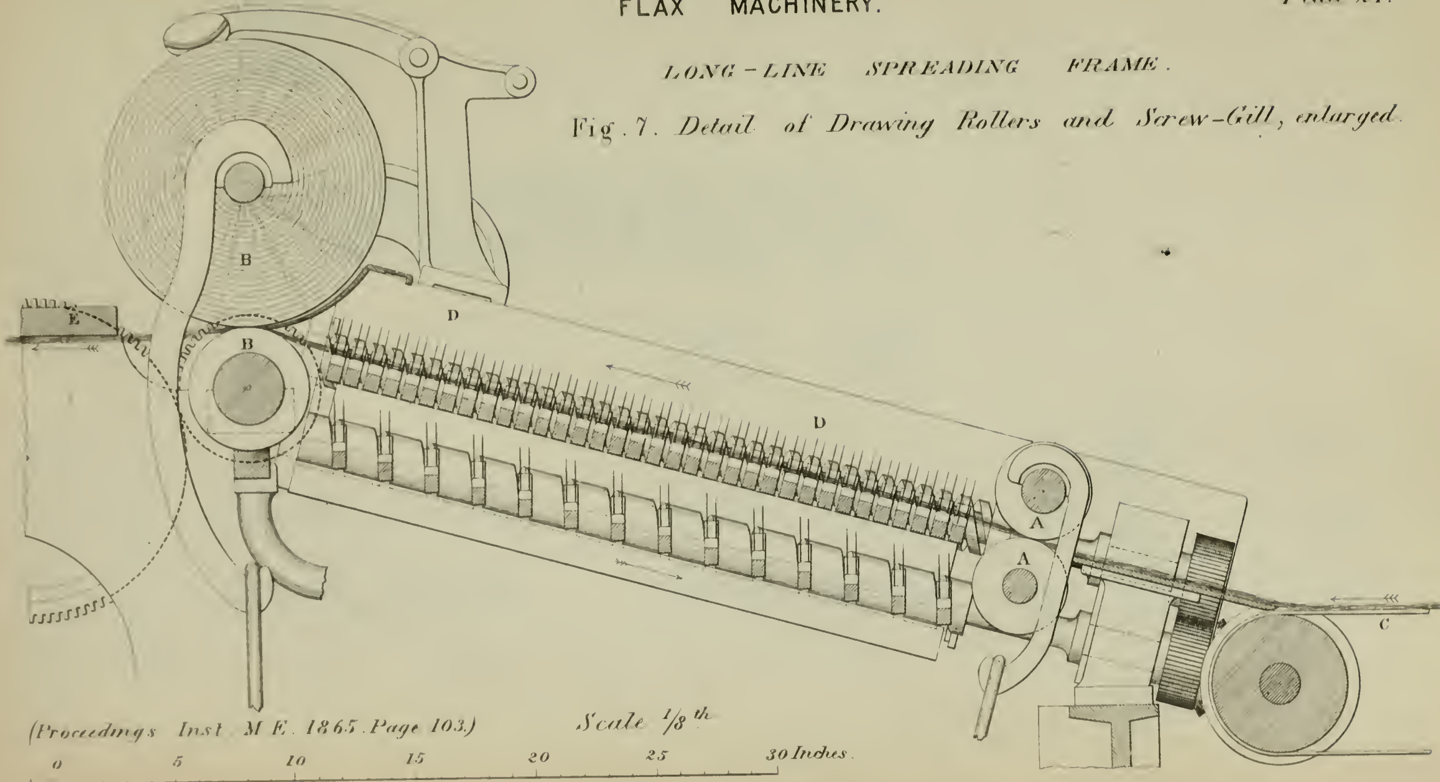


(Proceedings Inst M.E. 1865. Page 103.) *Scale 1/16th.*

FLAX MACHINERY. Plate 21.

LONG-LINE SPREADING FRAME.

Fig. 7. Detail of Drawing Rollers and Screw-Gill, enlarged.



Scale 1/8th

(Proceedings Inst. M. E. 1865. Page 103.)

FLAX MACHINERY.

LONG-LINE SPREADING FRAME.

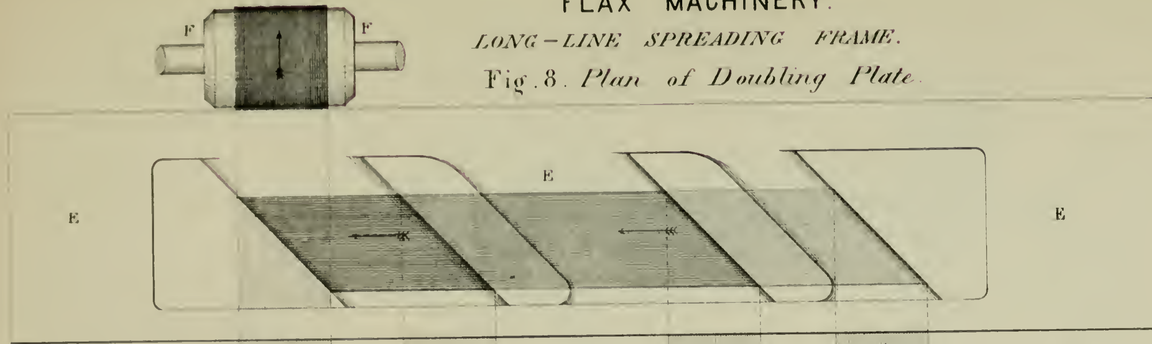
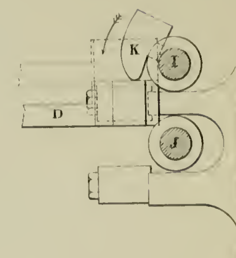


Fig. 8. Plan of Doubling Plate.

Fig. 10.



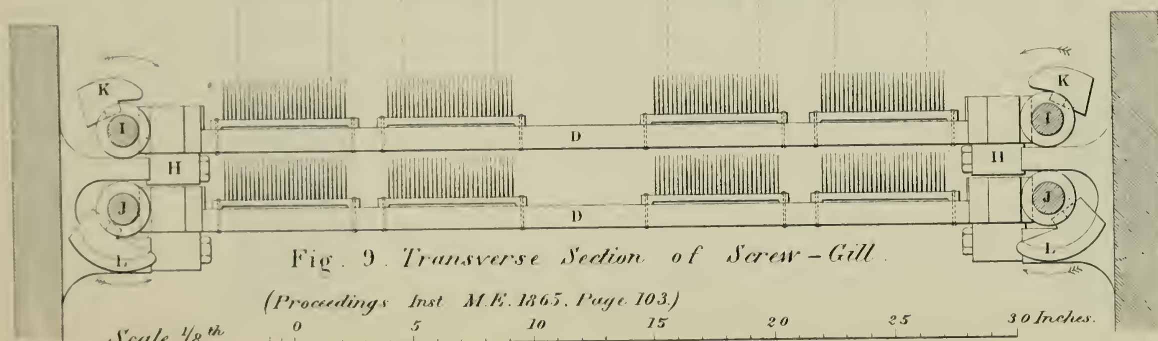
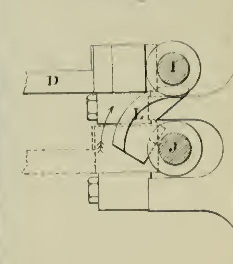


Fig. 9. Transverse Section of Screw-Gill.

(Proceedings Inst. M.E. 1865. Page 103.)

Scale 1/8th

Fig. 11.

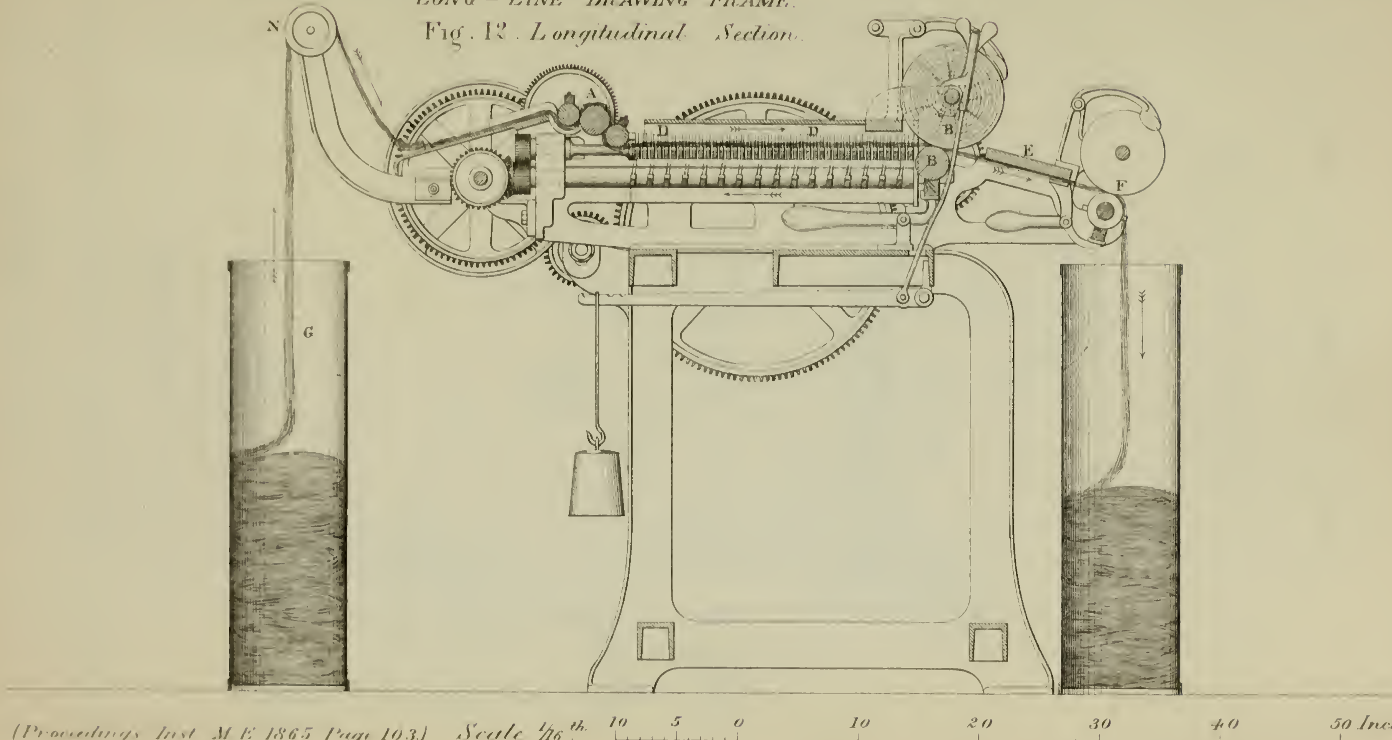


FLAX MACHINERY.

LONG – LINE DRAWING FRAME.

Fig. 12. *Longitudinal Section.*

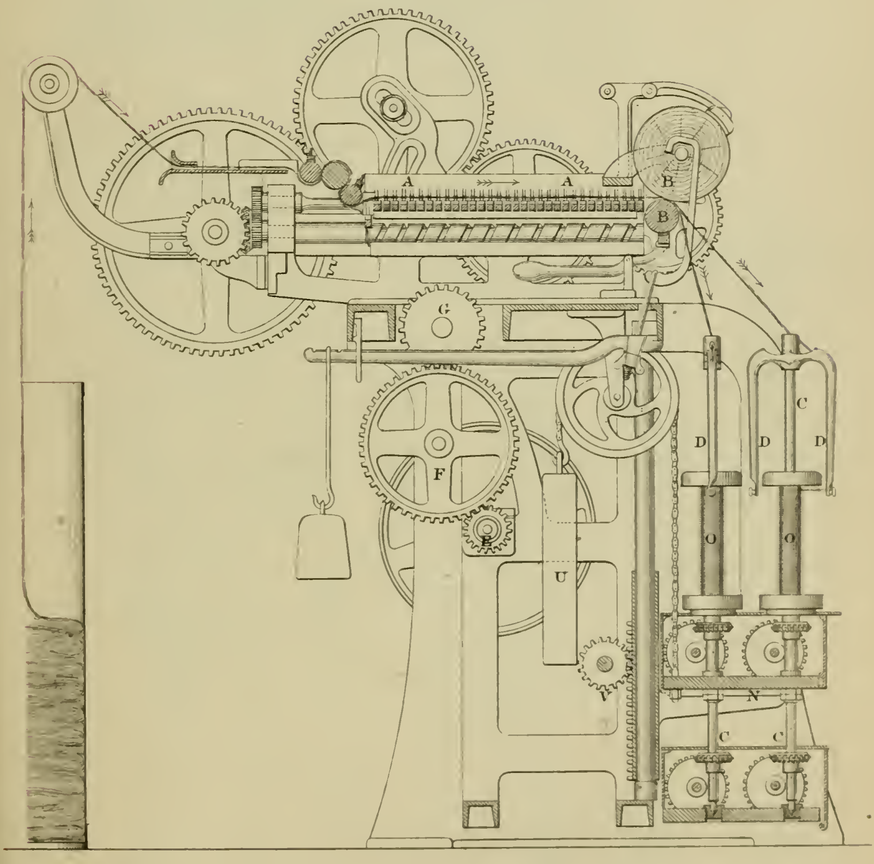
Plate 23.



(Proceedings Inst. M. E. 1865 Page 103.) Scale 1/16th.

LONG-LINE ROVING FRAME.

Fig. 13. *End Elevation.*

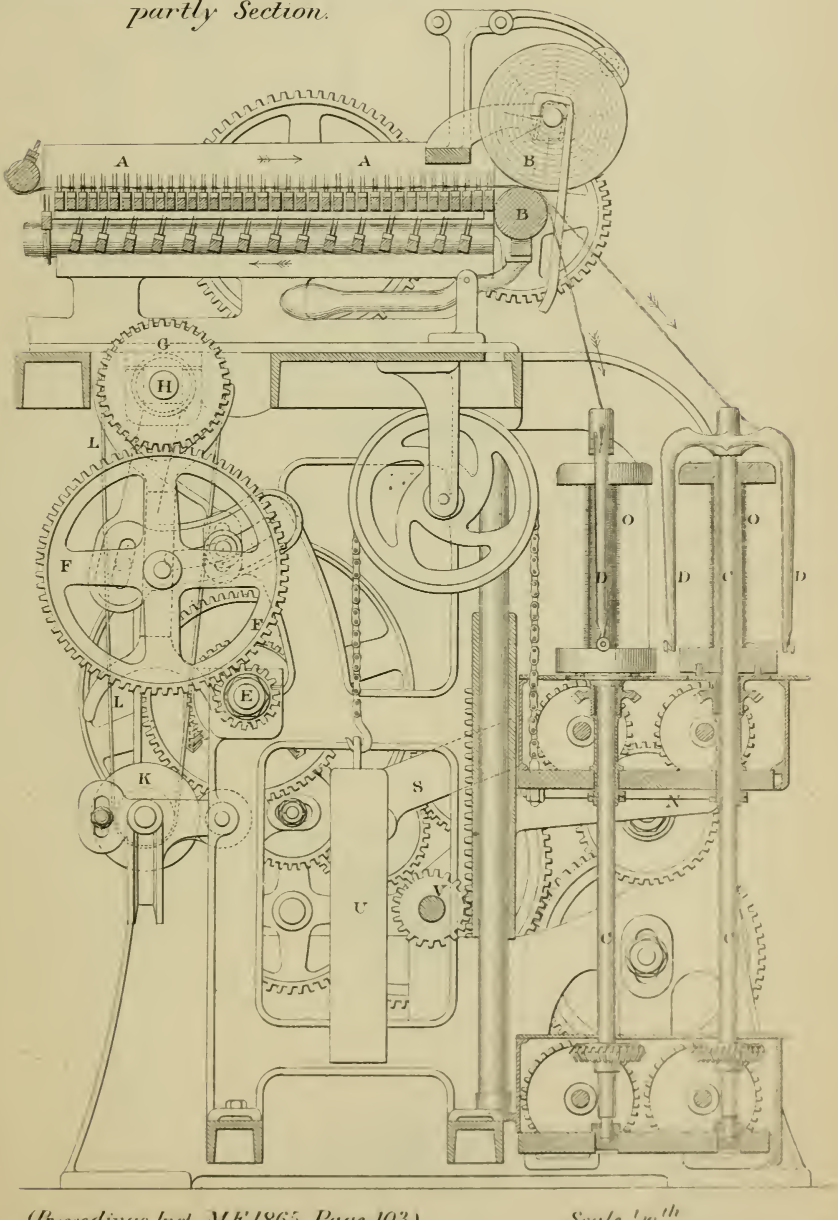


Scale 1/16th.

10 5 0 10 20 30 40 50 *Inches*

LONG-LINE ROVING FRAME.

Fig. 14. *End Elevation enlarged, partly Section.*



(Proceedings Inst. M.E. 1865. Page 103.)

Scale 1/10th

10 5 0 10 20 30 ins.

FLAX MACHINERY. *Plate 26.*

LONG-LINE ROVING FRAME.

Fig. 15. *Transverse Section of Regulating Gearing.*

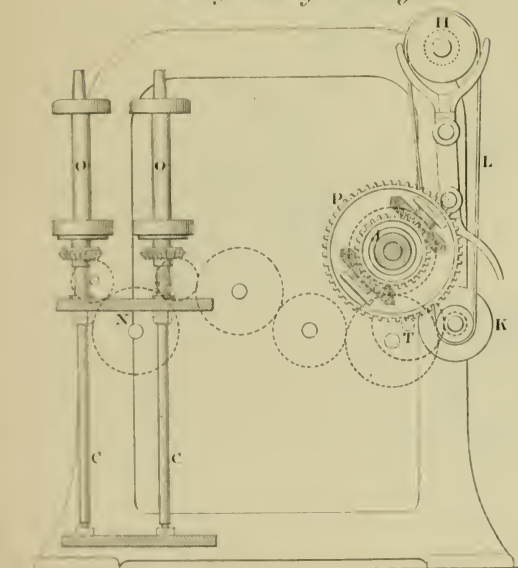
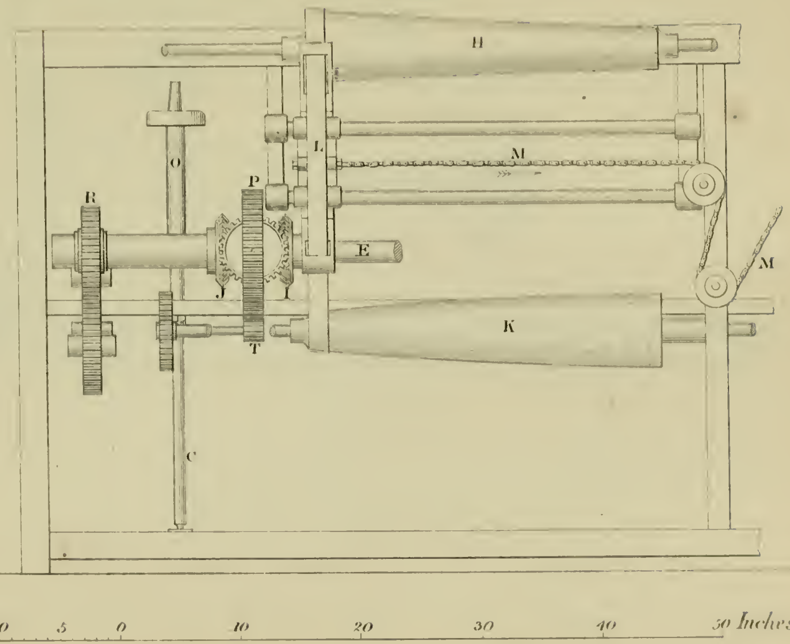


Fig. 16. *Back Elevation of Regulating Gearing.*

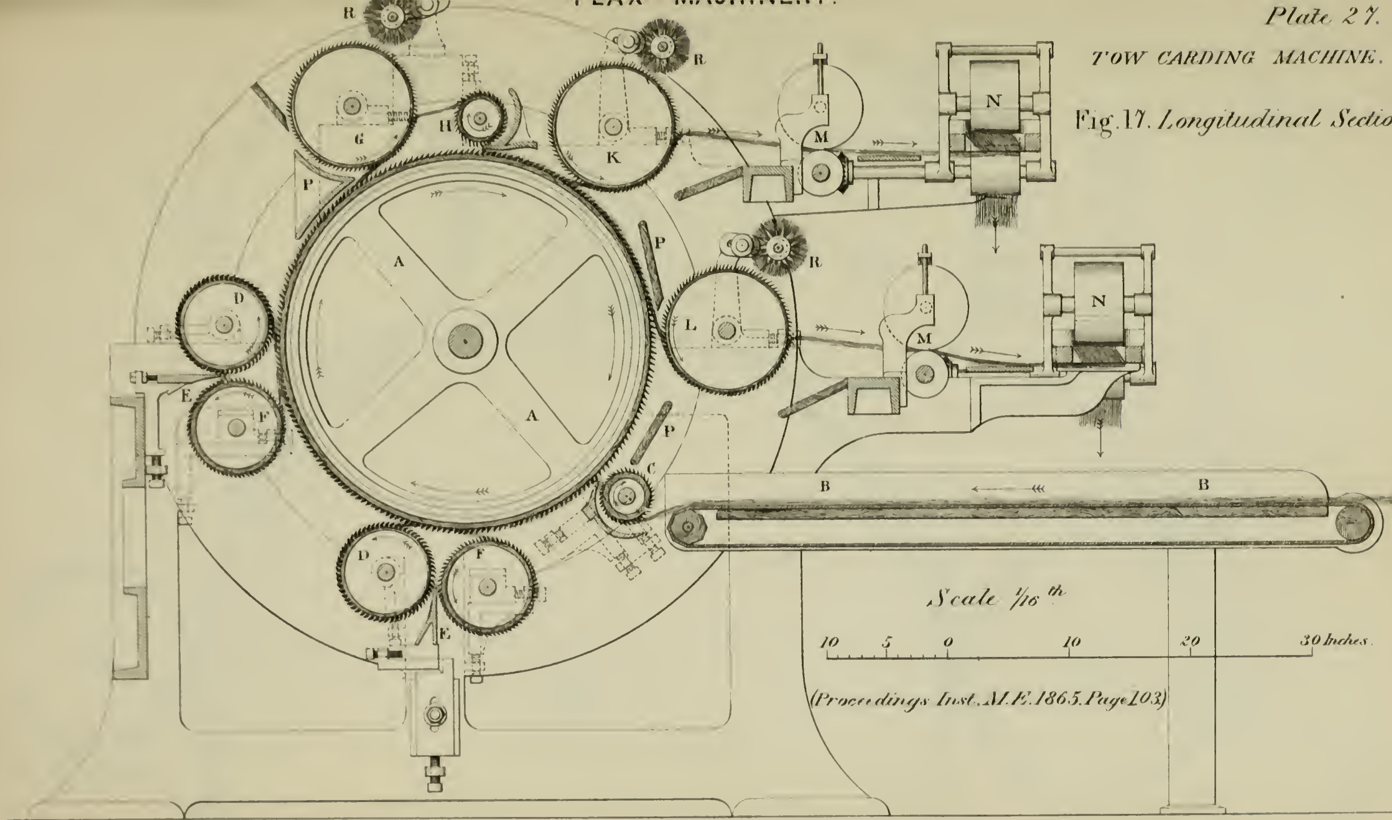


(Proceedings Inst. M. E. 1865. Page 103) Scale 1/16th

Plate 27.

TOW CARDING MACHINE.

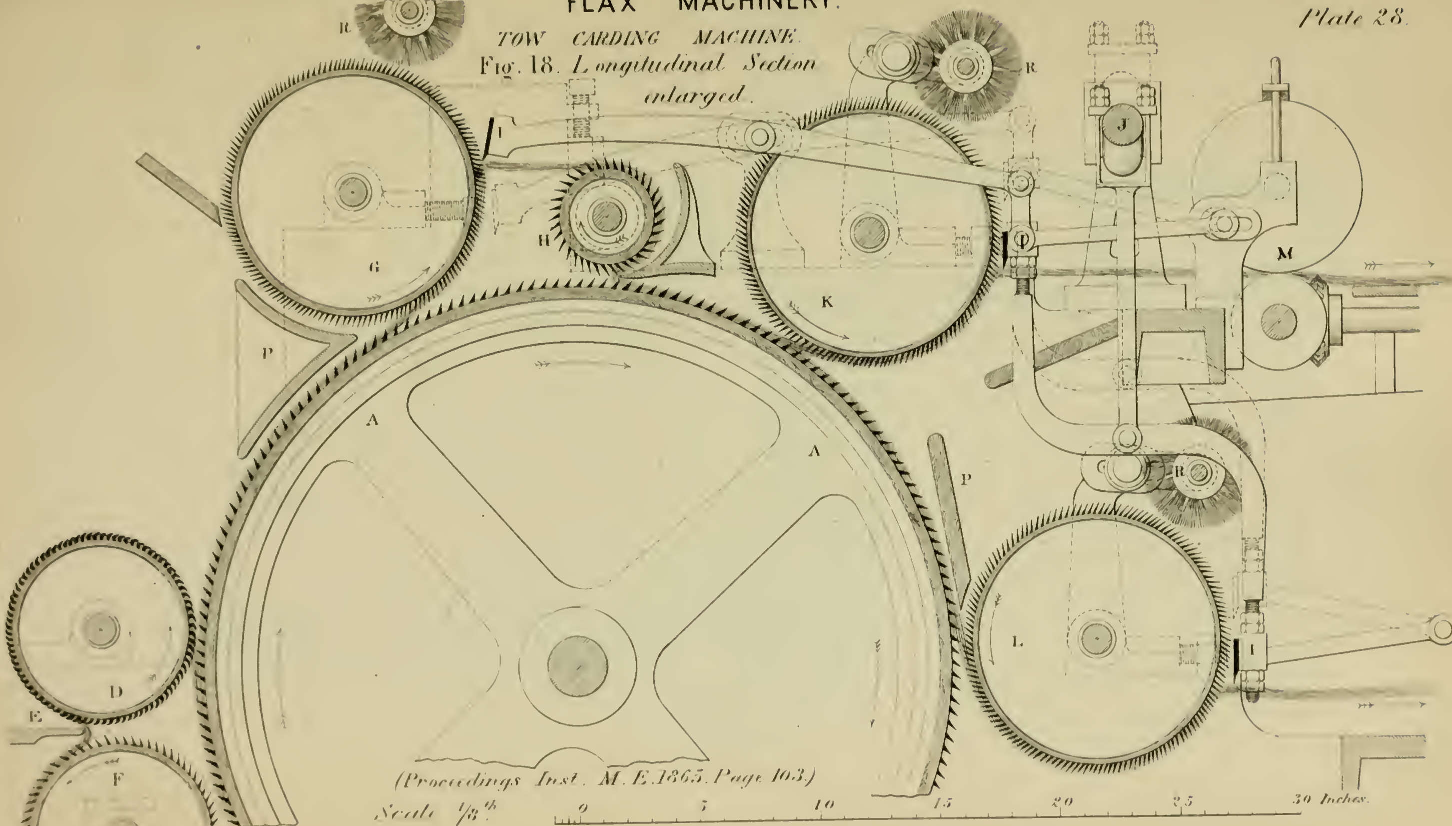
Fig. 17. *Longitudinal Section.*



FLAX MACHINERY.

TOW CARDING MACHINE.

Fig. 18. Longitudinal Section enlarged.

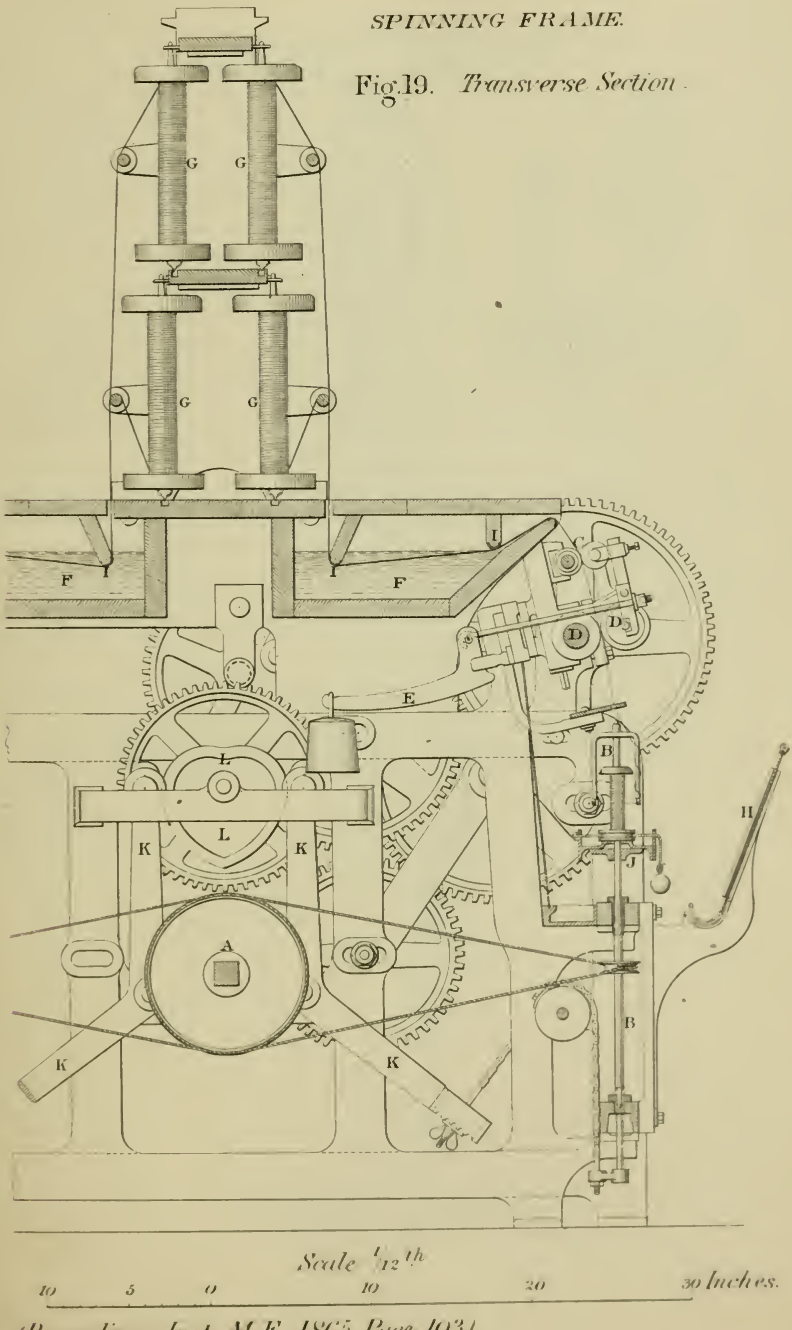


(Proceedings Inst. M. E. 1865. Page 103.)

Scale 1/8th.

SPINNING FRAME.

Fig. 19. *Transverse Section.*



Scale 1/12th

10 5 0 10 20 30 Inches.

PORTABLE STEAM RIVETTER.

Fig. 1. *General Elevation of Rivetter and Dolly.*

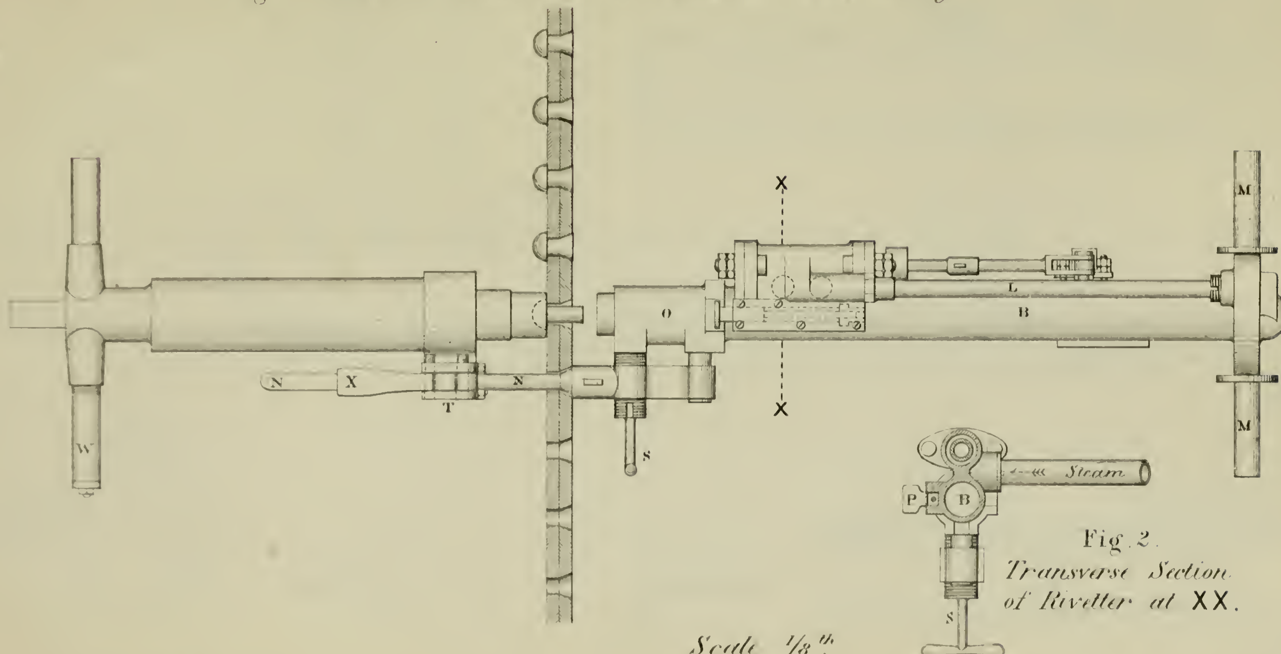


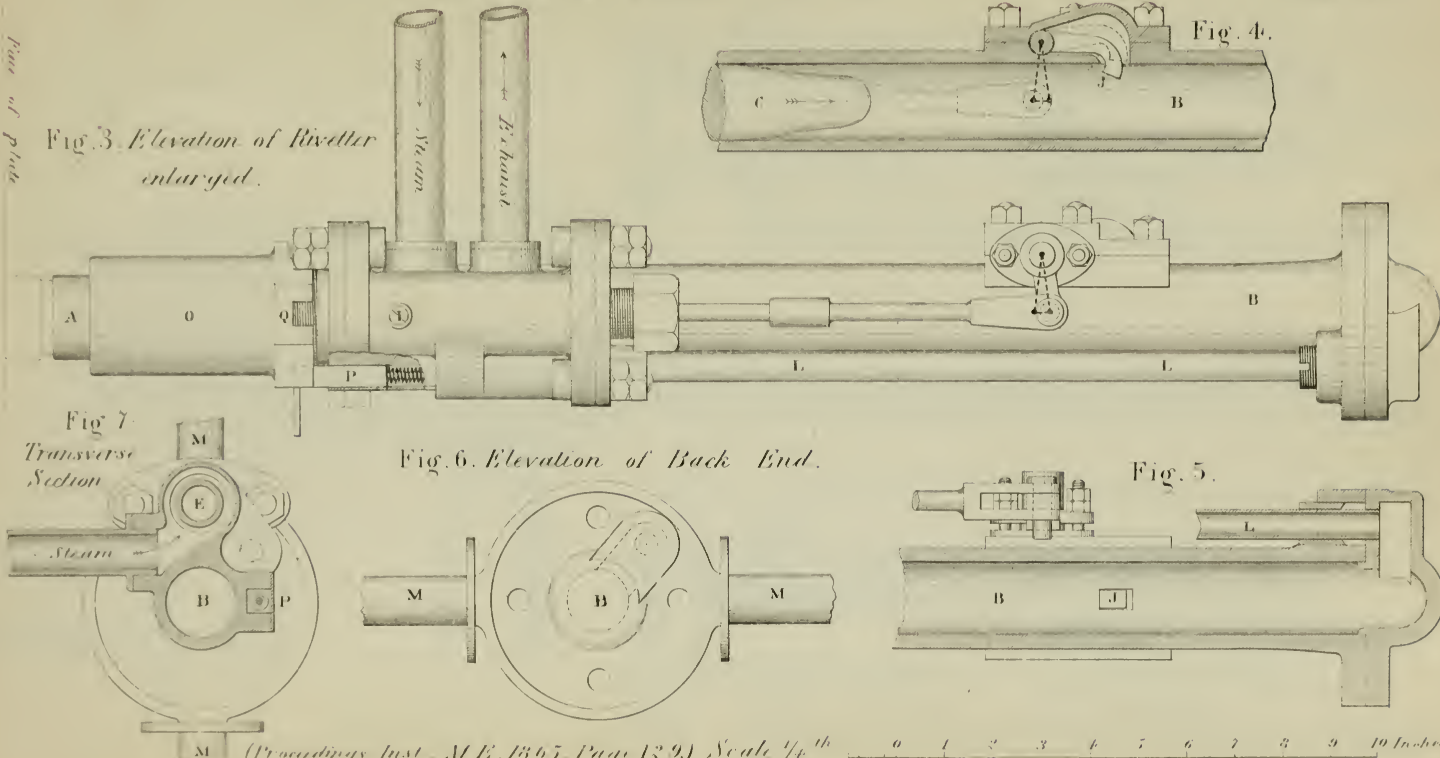
Fig. 2.
Transverse Section of Rivetter at XX.

Scale 1/8th.

0 10 20 30 *Inches*

PORTABLE STEAM RIVETTER.

Plate 31.



(Proceedings Inst. M.E. 1867. Page 129.) Scale 1/4th

Face of plate

PORTABLE STEAM RIVETTER.

Fig. 8. *Longitudinal Section enlarged of Steam Cylinder and Valve.*

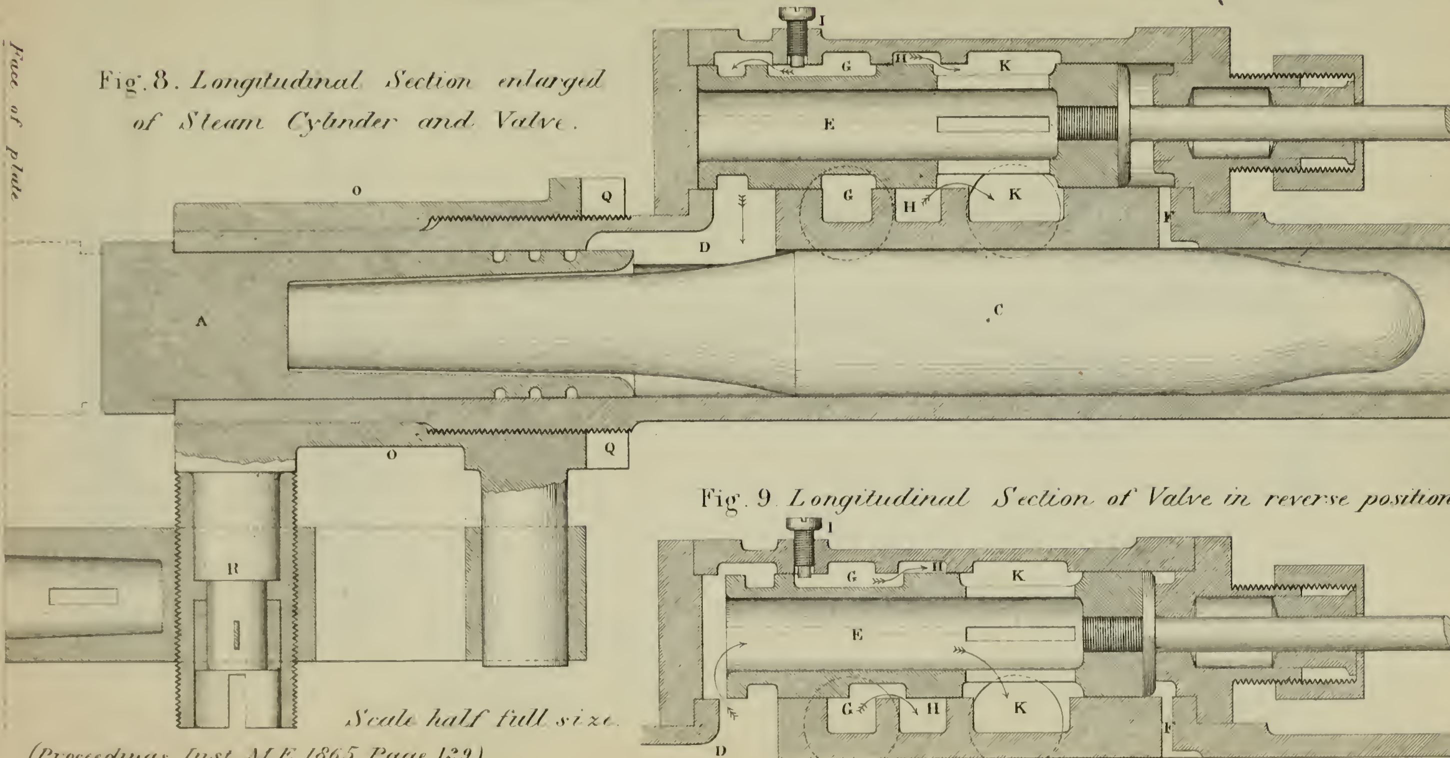


Fig. 9. *Longitudinal Section of Valve in reverse position.*

Scale half full size.

(Proceedings Inst. M E 1865. Page 129)

Face of plate

PORTABLE STEAM RIVETTER.

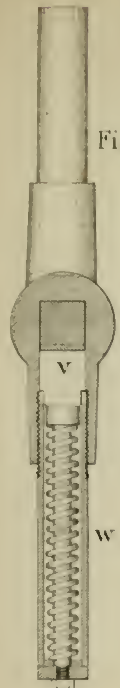


Fig. 11.

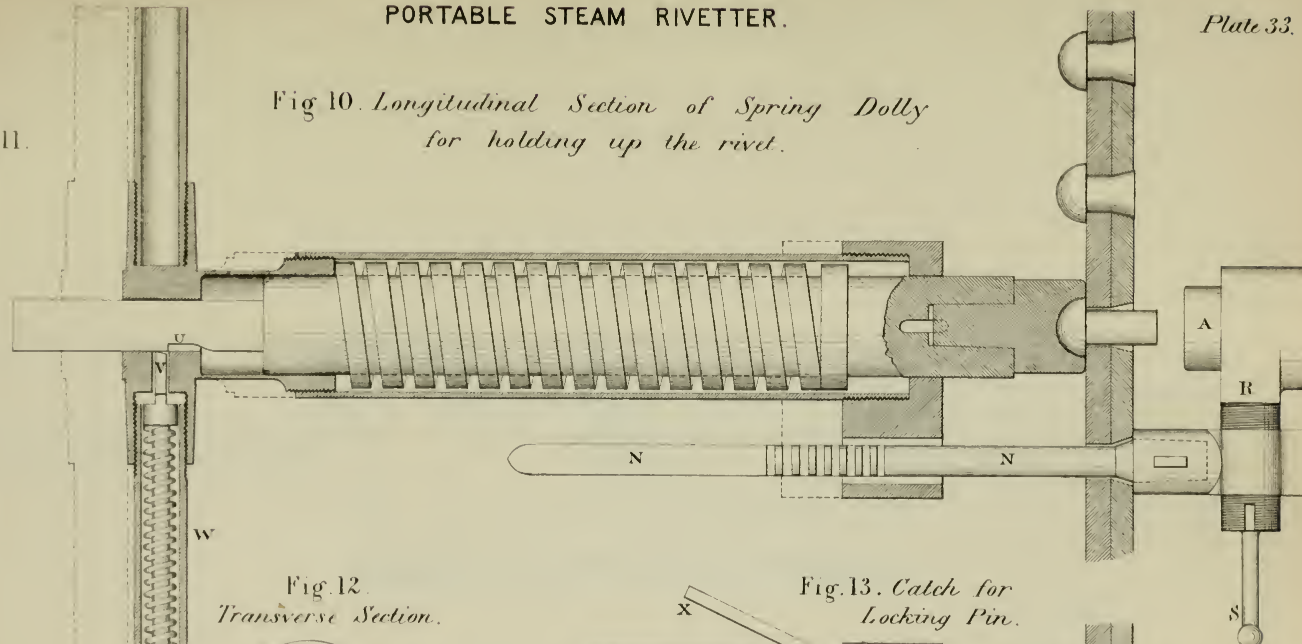


Fig 10. *Longitudinal Section of Spring Dolly for holding up the rivet.*

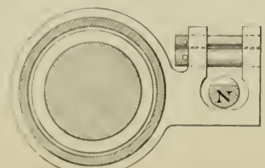


Fig. 12. *Transverse Section.*

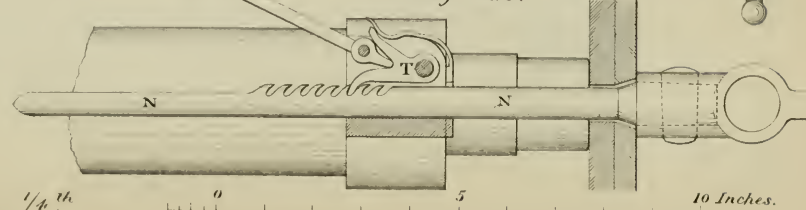


Fig. 13. *Catch for Locking Pin.*

Scale ¼th

PORTABLE STEAM RIVETTER. *Plate 34.*

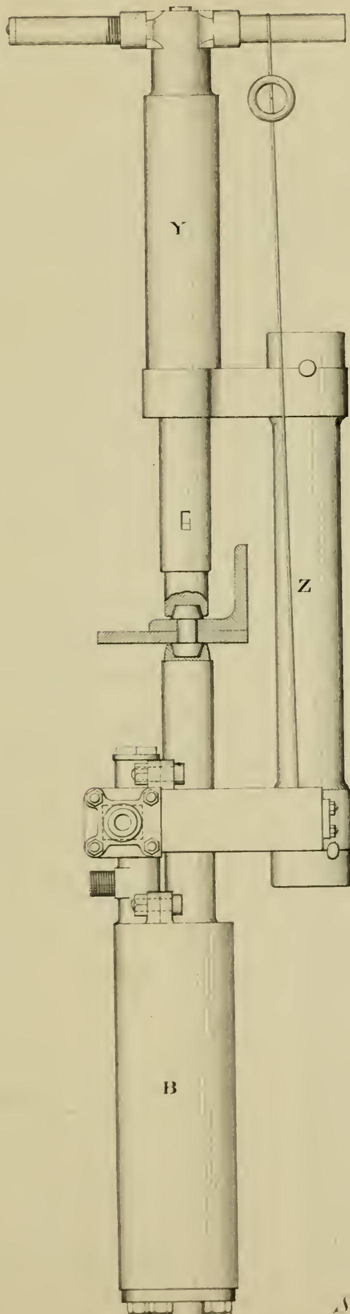


Fig. 14.
Elevation of Vertical Coupled Rivetter.

Scale 1/8th

0 5 10 Inches

PROCEEDINGS.

1 AND 2 AUGUST, 1865.

The ANNUAL MEETING of the Members was held in the Examination Hall, Trinity College, Dublin, on Tuesday, 1st August, 1865; ROBERT NAPIER, Esq., President, in the Chair.

The Minutes of the last General Meeting were read and confirmed.

The PRESIDENT announced that the Ballot Lists had been opened by the Committee appointed for the purpose, and the following New Members were duly elected:—

MEMBERS.

JOHN J. BAGSHAWE,	Sheffield.
CHARLES BELL,	Stoke-upon-Trent.
CHARLES BLADEN,	Jarrow.
GEORGE BROWN,	Rotherham.
FREDERICK WILLIAM BRYANT,	London.
SAMUEL CARLTON,	Swindon.
JOHN CLARKE,	Leeds.
VICTOR COATES,	Belfast.
JAMES CROSS,	St. Helen's.
JAMES DAVIDSON,	Woolwich.
CHARLES KELLOCH DOMVILLE,	Belfast.
CHARLES P. DOUGLAS,	Gateshead.
FRANK EVERS,	Stourbridge.
SAMUEL CLOUGH FAVIELL,	Leeds.
EDWARD FILLITER,	Leeds.
GÖRAN FREDRICK GÖRANSSON,	Gefle, Sweden.

F

William Arthur Harrison, . .	Manchester.
John Heptinstall, . . .	Rotherham.
John Muir Hetherington, . .	Manchester.
John Holliday, ...	Westbromwich.
Edward George Jarvis, . . .	Gloucester.
William MacNay, . . .	Darlington.
Daniel Macnee, ...	Sheffield.
Alexander McDonnell, . .	Dublin.
John Robinson, ...	Rochdale.
Alexander Thorn, . . .	London.
George Moon Usher, . . .	Beverley.
Andrew Wyllie, ...	Liverpool.

HONORARY MEMBERS.

Alfred Longsdon, . . .	London.
Thomas Warden, ...	Birmingham.

The following paper was then read :—

ON MACHINERY EMPLOYED IN THE PREPARATION AND SPINNING OF FLAX.

By Mr. THOMAS GREENWOOD, of Leeds.

The manufacture of Flax is from a variety of causes one of the most interesting of textile manufactures.; and although not one of the most extensive is of considerable importance, the exports of linen and linen yarn from this country amounting to upwards of £8,000,000 for the last year. As a manufacture it is one of the most ancient, the fine linen cloth of Egypt having been employed in a very remote period for embalming; and examination by the microscope confirms the fact that this cloth was made of flax and some of it of a fine quality. Yet there is not the slightest evidence that this linen was spun otherwise than by hand by means of the distaff, the method of spinning in those days being the same that prevailed in this country up to a very recent period, and is still extensively practised in the north of Europe in the neighbourhood of Archangel and the White Sea.

The processes of cultivating and retting flax seem to have been similar in all countries where it was grown, and steeping or dew-retting was the prevailing method in its preparation. Some years ago artificial methods were introduced to supersede this natural process of retting; but their success has only been partial, and in the chief flax producing countries the natural system prevails. The stalks of flax are pulled up by the roots and set up in bundles to dry, and the seed is then stripped off. The "retting" consists in steeping the stalks in partially stagnant water for about three weeks, during which time a fermentation takes place. The flax fibre being

the bark or rind of the flax plant, of which the interior or core is a semi-wooden substance called "boom," the object of retting is partially to decompose this woody substance, so that it becomes brittle when dry ; and the fermentation should not be continued so long as to injure the strength of the fibre, but long enough to loosen the gum which causes the bark to adhere to the woody portion. The process therefore requires great care and experience, for either too much or too little retting is detrimental to the fibre. When thoroughly dried, the flax is ready to be broken, which is done by passing it in small bunches through pairs of fluted rollers ; these break the woody core into short lengths, and also partially split the bark.

The next operation is called "scutching," which in most flax producing countries is still done by hand in preference to mill-scutching. In hand-scutching, a bundle of the broken flax is suspended alternately at each end and struck with a wooden beater, by which the broken pieces of the core or boom are dusted out from between the fibres. This operation requires considerable dexterity, for some of the finest flax is worth £200 per ton of fibre, so that any waste or damage to the fibre by getting it entangled is a serious loss. The bark or fibre at this stage ought to appear like narrow strips of tape ; unbroken and unentangled, or the yield will suffer in the next process of "heckling." In Ireland last year the flax crop covered upwards of 300,000 acres, producing 80,000 tons of flax at an average value of £60 to £70 per ton; and the hand-scutched flax realised about 20 per cent. higher price than the mill-scutched.

The next process is to "heckle" the flax, which was formerly done by hand by the flax dressers. The heckle is a board set closely with pins about 4 inches long, which are ground to a fine tapering point; this board is fixed with the points of the pins upwards, and the bundles of flax are drawn over the pins until the flax is sufficiently split. Other heckles of varying degrees of fineness are also used, partly to bring up the fibres to the requisite degree of fineness, but chiefly to clear out the short loose fibres or tow which were split off in the first heckling. The dressed flax was sold in

this state under the name of lint, for spinning by hand, which was formerly a common domestic occupation both of rich and poor.

In the early application of machinery to preparing and spinning flax, the fibres were drawn between two pairs of rollers, the first called the receiving rollers and the other pair the drawing rollers, the two pairs of rollers being placed at varying distances apart, according to the length of fibre to be operated upon. The drawing rollers ran at from 5 to 10 times the surface speed of the receiving rollers, so as to elongate the "sliver" or bundle of fibres. Subsequently a series of "travelling gills" was introduced between the receiving and drawing rollers, these being a succession of small transverse combs, called gills, travelling continuously forwards in the longitudinal direction of the fibres about 5 per cent. faster than the surface speed of the receiving rollers. This proved a step in the right direction, and was followed by the introduction of spinning frames similar to those employed in spinning cotton, but with the modifications rendered necessary by the difference in the material to be spun: the chief feature in the flax machinery being the great difference in the distance between the receiving and the drawing rollers, which amounts to as much as 20 to 24 inches distance in the case of flax, instead of at most only a few inches in the case of drawing cotton, on account of the great difference between the length of fibre in the two materials.

The flax was at first kept quite dry in the spinning process; but a mode of damping the yarn by means of a piece of wet cloth held in contact with the drawing roller was afterwards employed, which had the effect of laying the loose ends of the fibres in the same manner as is done by wetting the fingers in hand-spinning. But the great expansion that has taken place in the flax trade is due to the principle of wet spinning introduced by the late Mr. Kay: the flax rovings being first put into warm water and allowed to stand until fermentation took place, by which the flax was macerated and brought into a state bordering on putrefaction. This was found however to be a dangerous process, for if continued too long the strength of the fibre was destroyed. Subsequent

experience showed that it was only necessary to pass the rovings through hot water in order to attain a better result, and that no maceration was requisite. It is only the natural gum contained in the flax fibres that requires to be dissolved or softened, in order to allow them to be drawn asunder; and the slimy nature of the rovings when wet allows this to be done to almost any extent. When spun dry by machinery, No. 40 yarn was about the maximum degree of fineness attained, in which the "bundle" of 60,000 yards length weighs 5 lbs.,* and this size of yarn is suitable for ordinary linen cloth; but now by the improved process of wet spinning Nos. 300 to 400 are ordinarily attained, in which sizes of yarn the "bundle" of 60,000 yards length weighs only $\frac{2}{3}$ and $\frac{1}{2}$ lb. respectively. The whole of this advantage indeed is not due to the principle of wetting the roving, but many improvements in the preparation have contributed to the attainment of this result. One of the conditions of spinning flax wet is to bring the receiving and drawing rollers within a few inches of each other, and thus reduce the length operated upon of the fibre of the flax to the distance between the bite of the receiving and drawing rollers. Yet notwithstanding all the improvements of machinery, hand-spinning still produces a yarn of three times the fineness hitherto attained by the finest machine; for while Nos. 300 to 400 are the finest produced by the machines, the hand-spinner produces yarn from Nos. 1000 to 1200, in which the "bundle" of 60,000 yards length weighs only 1-5th and 1-6th lb. respectively. This finest kind of yarn, the value of which is equal to that of gold, weight for weight, is produced

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* The "bundle" of flax yarn consists of 200 leas or hanks of 300 yards each, making altogether 60,000 yards length; and the Nos. are marks indicating the sizes of the yarn in inverse proportion to the weight of the "bundle," as in the following table, the unit being No. 200 weighing 1 lb.:—

No. 10 yarn weighs	20 lbs.	per bundle	No. 200 yarn weighs	1 lb.	per bundle
No. 20	10 lbs.	,,	No. 300	2-3rds lb.	,,
No. 40	5 lbs.	,,	No. 400	2-4ths or $\frac{1}{2}$ lb.	,,
No. 50	4 lbs.	,,	No. 500	2-5ths lb.	,,
No. 100	2 lbs.	,,	No. 1000	2-10ths or $\frac{1}{5}$ lb.	,,
No. 200	1 lb.	,,	No. 1200	2-12ths or $\frac{1}{6}$ lb.	,,

chiefly in Belgium, and is used for making Brussels lace. The subsequent manufacture of flax after the yarn is produced presents great variety, the fabrics made from it ranging from the roughest "Dudley cambric" used for nail bags to the finest lawn, and from the stoutest ship's sail to the lightest gossamer lace.

Since the introduction of the principle of spinning flax wet, various methods have been adopted to render the fibre of the flax finer, or in other words to split it up into a greater number of fibres by the process of heckling. The quality of the flax varies very considerably, as indicated by the price, which ranges from £35 to as much as £200 per ton of fibre. In order to obtain the finest fibre it was found necessary to break or cut the flax into three lengths: the top of the plant, the middle, and the root end. Of these the middle is the best part, owing to the fibres being there most uniform in thickness. By this plan of dividing the natural length of the flax into three lengths, which is designated the "cut-line" system, a very much smaller proportion of short fibres is produced in the heckling process than by heckling the fibre the full length of the plant; and consequently the fibres can be split much finer, and a larger proportion of yarn can be produced from a given quantity of flax, the degree of fineness being taken into account. Another system is to cut the length of fibre in half; but this although partially pursued is wrong in principle, as the flax is then cut in the middle or most valuable part of the fibre, and each length has one bad end, the tapering end of the top of the plant, and the coarse end of the root. A third system is to heckle the flax the whole length of the fibre, which is called the "long-line" system, and is the most economical for the ordinary numbers of yarn that always constitute the great bulk of the manufacture. On this system a greater weight of flax can be passed through the heckling and preparing machinery in a given time; and a longer "draft" can be used at the spinning frame, that is the excess of surface speed of the drawing rollers above that of the receiving rollers can be made much greater than in the three-cut and two-cut systems, thereby producing a greater drawing action and making a finer thread, whilst reducing also the labour in attending to the process.

The machinery used in the three-cut and two-cut systems is the same as in the long-line process, only that in the former it is finer in the gills and rollers and shorter in the reach or distance between the pairs of rollers. For some descriptions of manufacture it is absolutely necessary to use the long-line process, as for instance in making the best kind of sail cloth, which is used in the royal navy and in the finest long-voyage vessels. For this purpose the longest and strongest flax is selected, and prepared with the greatest care in the processes of heckling, drawing, and roving, so as to preserve the fibres as long as possible; and in the spinning, which is done dry, very short drafts are used, that is the excess of surface speed of the drawing rollers above that of the receiving rollers is comparatively small, so as not to break the fibre any more than can be avoided. The government authorities insist upon a test of both weight and strength at the same time, in order to get the sails both strong enough to resist the wind and also as light as possible for the sailors to handle; for as the weight of the mainsail of a first-class ship amounts to more than a ton, it is no easy task to handle it in a gale of wind and rain.

The machinery at present in use for preparing the flax and spinning it into yarn for weaving &c. is shown in Plates 17 to 29.

Fig. 1, Plate 17, represents the Breaking Rollers, which are fluted iron rollers coupled together by spur wheels; and both top and bottom rollers are supported in journals, so as to prevent the flutes from touching each other. The spaces between the teeth of the flutes are also much wider than the teeth working into them, so that as the rollers revolve the flutes never come in contact; otherwise the iron would damage the fibre. The object of passing the flax between these rollers is simply to break the boom or woody interior of the flax.

After the flax has been broken between the rollers, it is taken to the Scutching Machine, shown in Figs. 2 and 3, Plate 17. The scutching cylinder A rotates in the direction of the arrow at about 300 revolutions per minute or 2,800 feet per minute speed of circumference, and dashes out the broken boom against the

grating D by means of the toothed and plain projections B and C. The drawing shows one pair of combs B and five pairs of plain square beaters CCC upon the cylinder A, which are found to act well; but the number of either may be altered. The strick of broken flax is fed into the machine by the attendant up to half its length; and when the boom is thoroughly beaten out, it is drawn back and the other half inserted in the same way. The broken boom beaten out through the grating D escapes by an opening at each end of the grating. The ends of the casing of the machine being closed, a considerable current of air is drawn in through the grating D by the rapid rotation of the scutching cylinder, which is an essential feature in this operation, in carrying away the refuse and dust, and producing a gentle pressure of the flax against the projecting beaters upon the cylinder. The bottom of the casing of the scutching machine is open, and communicates with a flue or culvert, through which the refuse and dust are carried away by the current of air.

The next process is to heckle the flax, and Fig. 4, Plate 18, shows an end elevation of the Heckling Machine. The flax is divided into small stricks, and each is held between a pair of clamps A called holders, made sometimes of hard wood but latterly of steel. These are closed firmly together by a bolt, as seen in Fig. 5, Plate 19, and are lined with either felt or india-rubber to form a cushion for the fibre to bed upon. The heckling machines vary in length, having sometimes four, six, or eight holders in a row; and the heckles BB have corresponding degrees of fineness, according to the amount of heckling that the flax will bear, the stricks of flax being submitted first to the action of the coarsest heckles, and then to the finer heckles in succession. The holders A are carried in a trough C, which extends the entire length of the machine, and also projects some distance at each end, so as to afford room for feeding in at one end the newly charged holders and removing from the other end those containing the heckled flax. The trough C receives a vertical motion from two cams D, shown by the dotted lines, mounted on the shaft E below, the weight of the trough being balanced by the

weighted lever F. The form of the cams D is so arranged as to bring the pendent end of the flax gradually under the operation of the heckles, and also to allow a slight pause when the trough has descended to its lowest point, as shown in Figs. 4 and 5, so that the heckles may comb out the fibres straight, and effectually clear out the tow. The trough C then rises again gradually; and when it has reached its highest position, as shown dotted in Fig. 4, the row of holders A are pushed forwards along it, by a series of pauls mounted upon a bar extending the entire length of the trough and acted upon by the lever G and cam H. Each strick of flax is thus carried along to the next gradation of heckles, and the trough C then again descends as before. The set screw I, Fig. 4, is for the purpose of adjusting the height of the trough A, so as to allow the holders to come down as near as possible to the bite of the heckles.

Fig. 5, Plate 19, represents an enlarged transverse section through the middle of the heckling machine. The sheets of heckles BB are made of leather straps passing round the small pulleys JJ at top, and round the larger driving pulleys KK below, travelling at the rate of about 800 feet per minute in the direction indicated by the arrows. The heckle bars LL are of wood, attached by only one edge to the straps B, so that when they have passed over the top pulleys JJ the heckle pins may strike into the pendent flax as nearly at right angles as possible, as seen at the top of Fig. 5. The heckles then descend in a vertical line until they reach the lower pulleys KK. These pulleys are grooved radially, and small slides carrying small iron rods MM are thrown out by the centrifugal force just below the centre of the pulleys. The rods M are for the purpose of stripping off any tow or short fibres of flax which may have remained between the heckle pins after they have passed through the flax; and as the pulleys K revolve, the rods M are pushed back into their former position by sliding against the guides N, until they reach the upper side of the pulleys, when their weight overcomes the centrifugal force; and they remain drawn back until again thrown out below the centre to strip the tow off the heckle pins. There are also a series of iron teeth OO attached to the inside of the leather straps B, which act as drivers to the straps, and keep the

heckle bars L always in proper horizontal position, by ensuring both the straps B being driven always at the same rate and without any chance of slipping; these teeth are driven by the teeth of the driving pulleys KK, and the small pulleys JJ at top are also notched to receive them, the inner faces of the teeth O being rounded off to the proper curve for forming part of the circle of the upper pulleys JJ in passing over them.

The main difficulty to be encountered in the heckling process has always been to obviate the large amount of waste that is made in the operation; and though heckling machines have been constructed in great variety, the same drawback of excessive waste has attended each, the proportion of the "dressed line," or finished flax after the heckling, being as small as only 40 per cent. of the flax put into the machine in the lower qualities of flax, but ranging in the better qualities from 60 to 75 per cent. Heckling machines are also sometimes made with double sets of heckles and holders, for the sake of economy of construction and working; and this may be an advantage in heckling the best kinds of flax. The lower qualities, such as Egyptian and some kinds of Baltic flax, require the least amount of heckling; whilst the best kinds of Flemish and Irish flax, which are strong in the fibre, are capable of being heckled to almost any degree of fineness.

In the next operation the dressed line or heckled flax, which has been obtained thus far in the form of a number of separate stricks of irregular thickness and quantity, is spread and drawn into a continuous sliver like a ribbon, by the combined action of a series of combs and drawing rollers.

Fig. 6, Plate 20, is a longitudinal section of the Long-Line Spreading Frame, so called because the distance between the receiving rollers A and the drawing rollers B is made long enough to take in the greatest length of fibre that has to be worked on the "long-line" system. The stricks of heckled flax are laid down upon the endless travelling feed sheet C, which carries the flax forwards to the receiving rollers A; and between these it passes on to the inclined bed of heckles or gills D, and then between the

drawing rollers B, through the doubling plate E, and between the delivery rollers F, which deliver the continuous sliver into the can G ready to be removed to the next process, the course of the flax through the machine being indicated by the arrows.

The heckle bars or gills D are supported at each end upon the slides H, as shown enlarged in Figs. 7 and 9, Plates 21 and 22 ; and they are traversed forwards towards the drawing rollers B by means of the upper pair of screws II revolving in one direction, and back again towards the receiving rollers A by the lower pair of screws JJ revolving in the contrary direction, each end of the heckle bar being inserted into a deep-cut groove in the screws I or J. This construction of machine is accordingly known as the "screw-gill" arrangement; and previous to its invention chains and other methods of propelling the heckle bars were employed. The heckle bars are carried forwards by the upper screws II till they arrive close to the lower drawing roller B, Fig. 7, when each bar in succession drops down at the end of the slides H into the groove of the lower screws J J ; these are made with a much longer pitch of groove than the upper screws I, partly to economise the number of heckle bars, and partly to ensure the bar which has just dropped into the lower screw being carried back sufficiently out of the way, to allow the succeeding bar ample room to drop in the same manner. A cam K, Fig. 9, is placed at the termination of the groove in the upper screw I, so that if the heckle bar should happen not to drop by its own weight into the lower screw, the cam K will force it down, as shown in Fig. 10. The heckle bars are then carried back by the lower screw towards the receiving rollers A ; and on each bar arriving close to the lower receiving roller, a cam L, Fig. 9, at the end of the lower screw raises the bar into the groove of the upper screw, as shown in Fig. 11, when the heckle pins penetrate the flax, and the heckle bar begins to travel forwards again towards the drawing rollers. The lifting cams L are continued through about one third of the whole circle, so as to support the heckle bar on a level with the slide H, until the screw I carries it a short distance along the slide, and thus to prevent it from dropping down again into the lower screw, which was a serious defect in the earlier screw-gills.

The screw-gills employed in the further process of preparing the flax for spinning are precisely the same in principle as those now described, only varying in their degrees of fineness. The system of screw-gill machinery shown in the drawings is called the "long-line" system, because by it the flax is worked the natural length of the fibre; and the machinery used for the cut-line and tow is just the same in principle, only shorter and finer to suit the length and fineness of the flax or tow operated upon.

The receiving rollers A, Fig. 7, travel at a surface speed of about 5 feet per minute, and the heckle bars about 5 per cent. faster so as to hold the flax in a slight tension. The surface speed of the drawing rollers B is from 15 to 30 times greater than the speed of the heckles, or from 70 to 140 feet per minute; consequently the fibres are combed or drawn between the pins, and the length of sliver delivered into the can G is elongated to about 15 to 30 times the length taken in by the receiving rollers A. One object of this operation is to lay the fibres parallel to one another, and also to prevent the long fibres from carrying the short fibres along with them and thus making an uneven sliver, which must produce uneven yarn. The upper of the drawing rollers B is made of wood, and is heavily pressed down by the links, levers, and weights M.

The flax is delivered from the drawing rollers B in a continuous sliver of ribbon-like form, from 4 to 5 inches wide, and four of such slivers are drawn by the machine, as shown in Figs. 8 and 9, Plate 22; these are then passed through the doubling plate E, and all four are rolled together into a single sliver of the same width by passing through the single pair of delivery rollers F. The doubling plate E, shown in plan in Fig. 8, has openings opposite each pair of drawing rollers at an angle of 45°, through which the slivers are passed, whereby they are caused to travel first at right angles to the line of delivery from the drawing rollers, and are afterwards turned again into the same direction towards the delivery rollers F, which deliver the final single sliver into the can G, Fig. 6.

The next operation is to re-draw and double again the sliver delivered from the long-line spreading frame; and Fig. 12, Plate 23,

shows the second Long-Line Drawing Frame. A number of cans G, generally eight, containing the slivers delivered from the spreading frame, are placed behind this drawing frame, whence the sliver passes over a high conductor N, in order to allow a considerable length to hang pendent and thus straighten out the creases made by pressing it down in the can G. The sliver then passes to the receiving rollers A, which are three in number, the object being to hold the sliver firmly and not allow the gills or heckles D to draw it beyond the surface speed of the rollers, which is about 6 feet per minute. The further operation of this machine is precisely the same as that of the spreading frame, the eight slivers being combed and drawn by the gills D and drawing rollers B, and then doubled by passing through the doubling plate E, and rolled into a single sliver by the delivery rollers F. The gills D however are finer and the rollers smaller than in the spreading frame. The speed of the gills is about $6\frac{1}{2}$ feet per minute, and the surface speed of the drawing rollers B and delivery rollers F about 130 feet per minute; and the length of the sliver delivered by the rollers F is consequently elongated to about 20 times the length taken in by the receiving rollers A.

The slivers from this machine are then taken to a third drawing frame, of precisely the same construction, but with still finer gills and smaller rollers; by this means the sliver is further elongated about 15 times, the object being to reduce it in width and thickness. From this third drawing frame the slivers are then taken to the roving frame.

Figs. 13 to 16, Plates 24, 25, and 26, represent what is known as the Screw-Gill Regulating Roving Frame, in which the delicate sliver of flax that has been produced by the previous processes is still further combed and drawn by gills and drawing rollers, and is then twisted into a roving and wound upon a bobbin.

This machine as a whole is perhaps the most complicated one used in spinning any kind of material, and has taken many years to bring it to the present state of perfection. The lower or regulating portion of the frame, by which the speed of winding the roving upon the bobbin is regulated according to the gradually increasing

diameter of the bobbin, is similar to that used in the cotton manufacture, where this system of machine was first introduced; but when so much of the machine as is used in the cotton manufacture is added to the screw-gill machinery, the two make what may be considered the most ingenious and perfect machine used in textile manufacture, and great ingenuity has been applied to overcome the numerous obstacles met with in perfecting this machine. The screw-gill part A, Figs. 13 and 14, is precisely the same as in the drawing frame last mentioned, only so much finer; for here the sliver is reduced to the smallest size previous to receiving the twist which changes it into a roving. The speed of the gills is about 6 feet per minute, and the surface speed of the drawing rollers B about 90 feet per minute, whereby the sliver is finally elongated about 15 times.

The special part of the roving frame, independent of the screw-gills and drawing rollers, is the regulating portion, situated in the lower part of the machine, which takes up the sliver as delivered by the drawing rollers, and after putting in the twist winds it upon a bobbin with a uniform but slight tension, not sufficient to elongate the delicate roving; and as each successive coil presents a larger diameter than the preceding, the speed of the bobbin has to be regulated or gradually increased for winding the roving, which is delivered at a uniform rate from the drawing rollers.

The bobbin spindles C C, Figs. 13 and 14, carrying the fliers D D, are driven at a uniform speed from the driving pulley upon the end of the main longitudinal driving shaft E, through a train of spur wheels driving the skew-bevil wheels at the bottom of the spindles C. The screw-gills A and drawing rollers B are also driven at a uniform speed by means of a change pinion on the end of the driving shaft E, through the intermediate wheel F working into the wheel G on the end of the top cone shaft H. The lower cone K, Figs. 15 and 16, receives its motion from the upper cone H through a strap L, which is made to travel longitudinally along the cones by means of a chain M passing over a pulley, with a weight hung at the end sufficient to draw the strap guide along two slide rods that extend the length of the cones or about $2\frac{1}{2}$ feet. The speed of the lower cone is thus varied according to the diameters of the cones at

the point where the strap may be working. The advance of the strap guide is governed by an escapement motion acted upon at each vertical reciprocation of the bobbin lifter N. The bobbins O O run loose upon the bobbin spindles C, and are themselves driven in the same direction as the spindles C through the intervention of the regulating gearing and the skew-bevil wheels carried by the bobbin lifter N.

Upon the driving shaft E is keyed a mitre wheel I, Fig. 16, which drives two mitre wheels mounted in the disc of the spur wheel P; and these again drive another mitre wheel J running loose upon the driving shaft E. A spur wheel R upon the boss of the last mitre wheel J drives the train of spur wheels indicated by the dotted lines in Fig. 15; these are mounted on the jointed rocking frame S, Fig. 14, and communicate motion to the longitudinal shafts in the bobbin lifter N, which carry the skew-bevil wheels that gear into the bobbin pinions. The bobbins OO are thus caused to revolve in the same direction as their spindles C, but at a somewhat slower speed. If the disc wheel P were not allowed to rotate at all, the bobbins O would be driven like their spindles at one uniform speed; and if the disc wheel P were driven at the same speed as the driving shaft E, no motion whatever would be communicated to the train of wheels which drives the bobbins O: therefore by regulating the motion of this wheel P any required speed can be communicated to the bobbins. A pinion on the shaft of the lower cone K gears into a train of spur wheels and pinions, so as considerably to reduce the speed at the pinion T which gears into the disc wheel P, thereby governing this wheel in accordance with the speed imparted to the lower cone. The rotation of the mitre wheel I keyed upon the driving shaft has a tendency to drive the disc wheel P at a considerable speed, so that the lower cone K is required to retard instead of actually driving it.

When the end of the roving is threaded through the flier D and then attached to the bobbin shank O, Fig. 14, the flier being fixed upon the spindle C will first put the twist into the roving, according to the number of revolutions, generally from $1\frac{1}{2}$ to 2, which the spindle makes for each inch of sliver delivered by

the drawing rollers B. Then the speed of the bobbin must be so much slower than that of the flier as to enable the flier by its greater speed to coil upon the bobbin the length of roving delivered by the drawing rollers. When one coil of roving has been laid upon the shank of the bobbin, its diameter is increased by double the thickness of the roving; and therefore before the next coil is wound on, the speed of the bobbin must be increased in proportion to the increased diameter. This is effected by each ascending and descending motion of the bobbin lifter N releasing a paul, which allows the strap L to be drawn along the cones H and K to a different diameter, and thereby varies the speed of the pinion T gearing into the spur wheel P. By this means the roving is wound upon the bobbin with an equal amount of tension and consequently a uniform thickness throughout the entire length wound. The different thicknesses of the roving, and consequently varying diameter of the bobbin when the coil is made with a thicker or thinner roving, are allowed for by the fineness of the teeth in the ratchet wheel of the escapement apparatus. The bobbin lifter N is counterbalanced by the weight U, Fig. 14, and the vertical reciprocating motion is given to it by means of a mangle wheel with pinion and rack V, driven from the lower cone K, so as to impart a gradually decreasing speed to the reciprocating motion of the bobbin lifter in accordance with the increasing diameter of the bobbin as the roving is wound upon it. These variations in speed can be so nicely adjusted that the bobbin will take up the whole length of the roving wound upon it, amounting to several hundred yards, without any perceptible difference in tension between the first coil and the last.

Figs. 17 and 18, Plates 27 and 28, represent a section of a Tow Carding Machine. The tow frequently contains a considerable quantity of dirt and boom that has been left in the flax by the scutching machine. This is principally removed from the dressed line in the heckling process, but is thrown down with the tow or shorter fibres of flax which are combed out by the heckles. The tow carding machine is intended to separate the dirt and boom

from the tow, and deliver the fibre in an even sliver ready for the drawing frame.

The large carding cylinder A, Figs. 17 and 18, is 2 ft. $7\frac{1}{2}$ ins. diameter, and is made of cast iron and covered with beech lagging set with finely ground and hardened steel teeth. The tow is laid upon an endless feed sheet B, which carries it forward to the feed roller C. Under the feed roller is a cast iron shell, the upper edge of which is carried up into the angle formed by the carding cylinder and the feed roller; and as the tow is slowly carried forwards by the feed roller at a rate of about 2 feet per minute, it is caught by the teeth of the carding cylinder A, which runs at about 300 revolutions per minute or 2500 feet per minute speed of circumference. The teeth of the cylinder A throw the tow against the worker D, which is a slowly revolving roller, running at a surface speed of only about 100 feet per minute, and covered with needle-pointed teeth set in strong leather. The teeth have a keen bend, as shown enlarged in Fig. 18, and carry the tow round towards the iron bar E, the upper edge of which is polished. The tow is then caught by the stripper F, which is clothed in a similar manner to the carding cylinder A, and runs much quicker than the worker D but slower than the cylinder A, having a surface speed of about 1500 feet per minute. The teeth of the carding cylinder then strip the tow from the teeth of the stripper F, and carry it forwards to a second pair of workers and strippers of exactly similar construction to the first, where the same operation is repeated for further cleansing and combing the tow.

The carding cylinder next carries the tow forwards to the doffer G, which is clothed with finely ground wire teeth set in leather, and moves very slowly at a surface speed of only 150 feet per minute. The tow is combed off the doffer by a comb I, Fig. 18, carried upon an oscillating arm worked by the crank shaft J, and it passes forwards to the feed roller H provided with an edge-plate or shell similar to the first feed roller C, and running at the same surface speed as the doffer G, feeding the tow again on to the carding cylinder A. As the speed of the carding cylinder is so very much greater than that of the doffer and feed roller, a further combing

action takes place upon the tow, by the teeth of the carding cylinder combing out the fibres, which are partially held between the teeth of the slow moving doffer and of the feed roller. The carding cylinder then carries the tow forwards to the second and third doffers K and L, where the final combing of the fibre takes place; and from these doffers the tow is combed off as before by the combs I I, where it is divided into three slivers, and passed forwards to the two pairs of rollers M and N, in connection with which is a doubling plate provided with angular openings, as previously described in the spreading frame. The last pair of rollers N N deliver the slivers of tow into cans ready to be taken away to the drawing and roving frames. It is usual to place a gill drawing apparatus in connection with the carding machine, so as to perform the first drawing operation at the same time, immediately upon the slivers of tow being delivered from the last pair of rollers N N; and this arrangement has been adopted as an improvement.

The action of the teeth upon the tow in the carding machine ought to be of a combing character, and in order to get this action the tow requires to be held up to the points of the teeth, which is effected in the improved carding machine shown in the drawings by means of the edge-plates E E, Figs. 17 and 18, inserted between the workers and strippers. The tow accumulates upon the worker D with its keen bent teeth, and is taken off by the stripper F; but the edge-plate E binds the tow into the angle between the two rollers and holds it up to the teeth of the stripper, thereby causing an amount of friction in the passage of the tow, and enabling the stripper by its quicker motion to comb out the fibres. In the ordinary carding machines, without these edge-plates between the workers and strippers, the tow is plucked in patches from the worker by the stripper, sometimes in such quantities as to roll up the tow, and in this state it is carried back to the carding cylinder, thus breaking the fibre and making uneven work. Carding machines have for a long time been made with cylinders as much as 5 feet diameter, and a considerable number of pairs of workers and strippers, say from six to eight or even nine pairs; but in these

the work produced is in no way superior, and a much larger amount of waste is made and more power used. Wooden guards P P, Fig. 17, are fixed in different positions round the circumference of the carding cylinder, for the purpose of directing the currents of air caused by the rotation of the cylinder so as to disturb the tow as little as possible in its passage between the points of the teeth of the several rollers running in contact with the carding cylinder, in order thereby to avoid waste and imperfect work. The teeth of the doffers G, K, and L, are kept clean by the brushes R R driven in the opposite direction.

The after processes of drawing and roving the tow slivers as delivered from the carding machine are precisely similar to those in the long-line preparation already described, the drawing and roving frames for the tow being adapted to the shorter fibre to be worked. Several kinds of gills have been introduced for preparing tow, but none have proved an improvement upon the screw-gill, which is now almost universally used in flax machinery. The process of combing tow by a combing machine, after carding it, is carried on by two or three eminent spinners, but the cost is out of all proportion to the quality of yarn produced; and the tow thus prepared is only used for making sewing thread, to which it has been successfully adapted.

The last process in the manufacture of yarn is the spinning; and in Fig. 19, Plate 29, is shown a transverse section of rather more than one half of a wet Spinning Frame.

The cylinder A drives the spindles B, which carry the fliers for spinning the yarn, at a uniform speed of from 2000 to 4000 revolutions per minute, the speed being adjusted according to the weight and quality of yarn produced. C are the receiving rollers, and D the drawing rollers, which are called the back and front pair of rollers respectively; and the difference of speed is usually from 8 to 10 times, thus drawing out the roving to about one tenth of its size. The upper roller of each pair is pressed against the lower by the saddle and weighted lever E. The hot water trough F through which the roving passes is placed with its edge as

near as practicable to the bite of the receiving rollers C. The bobbins G from which the roving is supplied are placed above, and the roving is held down in the water by strips of wood II faced with sheet brass. A splashboard H is fixed in front of the spinning frame, to prevent the spray from the wet yarn being thrown upon the attendants.

The lower of the two drawing rollers D is driven by a train of wheels from the main driving shaft A at a uniform speed of from 100 to 200 feet per minute of the circumference, so that the fliers make from 20 to 40 revolutions for each foot of yarn delivered by the drawing rollers; and this additional amount of twist put into the wet sliver converts the delicate roving into a strong yarn. The yarn bobbin is loose upon the spindle B; and as the length of yarn given out by the drawing rollers is very much less than the length which the flier would wind upon the bobbin if the latter were stationary, the bobbin is simply dragged round by the flier in the same direction as the spindle B, without requiring any regulating gearing for driving the bobbin as in the case of the roving frame, since the yarn is too strong to be elongated or injured by the tension necessary to drag the bobbin round. In order to keep sufficient tension upon the yarn whilst winding upon the bobbin, so as to prevent "snarls" in the thread, a cord is pressed against a groove in the bottom flange of the bobbin, the friction of which retards the bobbin and produces the required tension upon the yarn: one end of this cord is fastened to the inner edge of the bobbin lifter J, and the other end hangs pendent with a weight through a notch in the outer edge of the bobbin lifter, which is notched along its entire length; thus the amount of friction upon the bobbin can be varied as desired by shifting the cord into a different notch, thereby varying the length of the arc of contact of the cord with the bobbin flange. The bobbin lifter J is raised and lowered at a uniform rate by the lever K worked by the cam L, which is driven from the main driving shaft A.

The important point in a spinning frame is to have good rollers. The receiving rollers C and the lower of the drawing rollers D are made of hard brass, and all three are very carefully fluted longitu-

dinally with flutes that have a round top and bottom, so that the roving as it passes through the receiving rollers may not be unevenly crushed, which would cause the fibre to break down in the drawing process. The drawing rollers D have the upper or pressing roller made of soft material, usually boxwood, but the warm water used in the process is very destructive to the wood; gutta-percha also has long been tried, but if not well purified from sand or earthy matter it is apt to wear away the brass roller.

Scarcely any improvement has been made in the spinning frames for a great number of years, and they are practically the same as employed a few years after the introduction of wet spinning, which so completely revolutionised the flax manufacture. The heat of the steam from the hot water troughs and its condensation in the spinning room render this part of the manufacture anything but agreeable to the attendants, especially where the most strict sanitary rules are not enforced: a drawback to which the flax manufacture will most likely have to submit, until some other vegetable fibre that does not require wet spinning can be found to take its place.

The PRESIDENT remarked that they were greatly indebted to Mr. Greenwood for his very interesting paper just read, which had been kindly prepared by him for the present meeting of the Institution in Dublin, in compliance with the special request of the Council, as the subject was one of particular interest and importance in Ireland.

Mr. GREENWOOD exhibited in action one of the screw-gill machines of the make employed for drawing silk, in order to show the construction and working of the screw-gill; and he explained that the machine employed in the case of flax was exactly similar in construction, only larger and coarser in the pitch of the gills and combs, and the silk-drawing machine now exhibited was without

the angular doubling plate by which the several slivers of flax were directed into the same line and passed together through the delivery rollers so as to be rolled into a single sliver.

The President enquired what was the cost of a flax mill fitted up with a complete set of the machinery described in the paper, in comparison with the cost of mills for spinning cotton.

Mr. Greenwood replied that the cost of the mill was generally reckoned at so much per spindle of the spinning frame; and about twenty spindles were required in the spinning frame to absorb the work of one of the spindles in the long-line roving frame; and one spreading and two drawing frames were required to feed one roving frame of fifty spindles. Including the whole cost for the set of machinery, steam engine, shafting, and building, a flax mill might be put up for about £4 per spindle of the spinning frame. The spinning frames themselves were worth from 16*s.* to 25*s.* per spindle, according to the degree of fineness of the yarn to be spun, some being made with only 2 inches pitch from centre to centre of the successive spindles, and others as much as 4 or 5 inches pitch. A cotton spinning mill was very much cheaper than a flax mill per spindle of the spinning frames, but he could not state the difference of cost. The weight of thread produced per spindle was however much greater with flax than with cotton, and the material itself was also more valuable.

Mr. W. Richardson said that the cost of machinery for spinning cotton varied according to the counts of yarn to be spun. For medium numbers, say from 30 to 40 hanks to the pound, a large mill had been built and fitted with machinery during the crisis caused by the American war for a total cost of 14 shillings per mule spindle.

The President enquired where the China grass was grown from which the sliver that was exhibited had been produced, and what sort of plant it was.

Mr. Greenwood replied that the China grass was simply a rank weed or nettle, similar to the common nettle of this country but growing to ten times the size, and indigenous to China, Java, the East Indies, and some other countries. The interior of the plant

contained the fibre, and the outside rind and green matter had to be removed. It was produced in the largest quantities in China, where it was woven from the split fibre without being spun. It was also used for ships' cordage, of which some very good samples had been seen in this country in the Chinese junk that lay in the river at London some years ago. If there were a regular business demand for China grass it could be supplied from Java at £35 per ton in London or Liverpool, and he had no doubt that in a few years' time it would hold a very important place among textile fabrics. He showed the process of drawing the fibre into slivers in the machine exhibited from the partially prepared state in which the material was supplied to the market; and stated that in the form of sliver it was sold to the worsted and silk manufacturers, for mixing with those materials, and could be spun quite well by itself without any difficulty, forming a most useful material for dresses. China grass was also grown in Algeria, and he believed in the south of France; but it was of smaller size in those cases, and the best was from China and Java, the plant requiring a hot sun and humid atmosphere for its full growth. The Emperor of the French had offered to import it free of duty into France for the trade, if the French manufacturers would use it.

The President enquired whether the common nettle of this country had been tried in the same manner as the China grass, and whether it contained fibre that could similarly be made use of.

Mr. Greenwood replied that the common nettle of this country also contained fibre that could be spun like the China grass; but it would be too dear to be made use of practically, because there was not a sufficient supply of fibre in the plant to make it of any commercial value, and moreover there was more difficulty in extracting the fibre from the small stem of the common nettle than from the large stem of the China grass.

Mr. W. E. Newton thought it seemed strange that China grass, which could be obtained at considerably less than half the cost of flax, should not be more generally used; and he enquired whether there were not some practical difficulties connected with the working of that plant, which did not exist in the case of the flax plant. He

had heard that with China grass there were some peculiar difficulties in the way of getting the fibre from the rough plant. Many attempts had been made to get materials for spinning from other fibrous plants, such as the common nettle and other plants growing in this country; but the difficulty had hitherto been almost insurmountable of getting the valuable fibre away from the woody part of the plant. The common stinging nettle indeed, which was indigenous to Ireland and Great Britain, contained a fibre as fine as that of the flax plant itself, or perhaps even finer; but it would be impossible to obtain a sufficient supply of the plants from the hedgerows and highways, and it would not be worth while to lay out land specially for growing nettles. The same objection arose in the case of the manufacture of paper, which might be made out of almost any weeds, but could not be produced commercially from such sources, because it was not possible to procure a sufficient and regular supply of the weeds for this purpose. A great deal had certainly been done already with regard to China grass, and Messrs. Marshall of Leeds had carried on an extensive series of experiments with it, and had succeeded at last in producing a pretty good yarn; but there seemed to be still some inconveniences and difficulties remaining, which prevented the China grass from being more generally adopted, and he would be glad of some further explanation in reference to this subject.

Mr. Greenwood said that about fifteen years ago Messrs. Marshall endeavoured to bring the China grass into use for yarn, and produced a considerable quantity, which was afterwards manufactured into a kind of cambric handkerchiefs. The prices at which the raw material was sold were very irregular, on account of there being no regular demand for it. The plant grew in a sort of jungle, and was cut down by the natives; and by what process the bark was stripped off in the first instance he did not know, but believed it was done by hand by the Chinese, as the material was very extensively used in China. It was imported into this country in long stricks of fibre of a brown or dark kind of cream colour, and when prepared and dressed was easily bleached. If the fibre were intended to be dyed, it was much better for this to be done without

bleaching. The processes of preparing the fibre, which was very stubborn and strong, had been attempted in a variety of ways ; but it appeared that almost the only thing it required was washing with plenty of soap and warm water, in order to reduce it to a fine soft silky state. After being well pounded in soap and water the material was laid out to dry, preparatory to splitting. The splitting was done by spreading out the dried material in a layer about 15 inches wide and $1\frac{1}{2}$ inch thick, and it was then perforated by a number of fine sharp points fixed on a board, which had a slight shogging motion given to them of about 1-8th inch in order to assist the pins in splitting it up into its separate fibres. It was afterwards passed through a combing machine similar to a wool combing machine, in which it was combed out and delivered in tufts of about 9 or 10 inches length of fibre and subsequently converted into the form of a narrow sliver. In this state the China grass was supplied in large quantities to Bradford, where it was mixed with wool in the sliver, and gave to the wool what was called a spinning quality. Formerly silk was used for that purpose, the object being to spin out wool to a very much finer thread than it would spin to alone. The compound thread thus spun was used in Paisley for making beautiful tartan dresses, in which the great aim was to get the dress as light as possible: when silk was mixed with the wool sliver the tartan was one third lighter than if made of pure wool; and China grass seemed to offer nearly the same facilities as silk for combination in this manner with wool, and at only about one fourth of the price of silk, the sliver of China grass being sold in Bradford at about 3*s.* 6*d.* per lb., or even less than the cost of wool, whilst the cost of silk was about 15*s.* per lb. The China grass could be spun either pure or mixed, and when afterwards woven with silk warps it produced some of the finest fabrics that had been seen, giving them a kind of transparent glassy appearance in the sun which could not be obtained by any other material at present known of. All the difficulties in preparing the sliver seemed now to be entirely overcome; and without carrying the manufacture any further than the state of sliver, an enormous quantity of this could now be sold. It was indeed a cheaper fibre than any other, considering

the degree of fineness, and he had no doubt that in a few years it would be a very important textile material in this country. The reason why Messrs. Marshall's endeavours to spin the China grass had not proved altogether successful was he believed that they had only tried spinning the fibre wet, in the same manner that flax was spun; but the dry process was now found to be the only one by which the China grass could be spun. The effect of wet upon the fibre was clearly shown by taking a small roving of the China grass in the fingers whilst dry, when a breath would almost blow it apart into its original separate fibres; but if the same roving were wet with nothing but cold water and slightly twisted together, it would require considerable force to break it, and this was the difficulty in spinning the fibre wet. An examination of the China grass showed that each fibre was perfect in itself, and could not be split up *ad infinitum* like the flax fibre. In this respect it was like wool, and consequently could be spun very easily indeed, provided the spinning were done dry.

Mr. J. Whitley enquired what was the comparative strength of the yarns of China grass and of ordinary flax.

Mr. Greenwood thought the China grass was rather the stronger, and he had had some samples of sewing thread made from it, which compared favourably in point of strength with the ordinary linen thread. In respect to wearing qualities he believed it was considerably more durable than flax.

The President enquired whether any comparison had been made between the strength of handspun flax and that spun by machinery.

Mr. Greenwood thought the handspun flax was a little stronger, the fibre being better preserved in spinning by hand than by machinery.

The President enquired what improvements were at present considered to be needed in flax machinery, or whether it was thought to have been now brought into a state of such practical perfection as not to require any further material improvement.

Mr. Greenwood replied that the machinery was of course still imperfect in some respects, but he did not see at present how it

was to be made more perfect; within the last few years a little had been done towards improving it, but not much, and there did not appear to be any very important improvements remaining to be effected. Since seeing the process of preparing the China grass fibre, his impression was that finer qualities of flax might be prepared in a similar manner, and he was now engaged in making some machinery for that purpose. The main object now to be aimed at in the flax machinery was to get rid of the heckling machine and the spreading frame: in the heckling machine a waste of the flax was occasioned by the process of heckling, and in the spreading frame the operation of laying down the stricks of flax for feeding the machine was still done by hand, and was therefore liable to be performed carelessly and irregularly. In the preparation of the sliver of China grass that was exhibited these two processes had been entirely avoided, and the sliver was delivered in one process direct from the stricks of crude fibre by means of a combing machine of peculiar construction, in which the combs were very fine and the pins were presented at an acute angle to the surface of the sliver, thus clearing away all the short fibres and any small portions of bark or green substance which might by chance be left upon the fibre; and he thought the same treatment might be advantageously tried in the case of flax also.

The President proposed a vote of thanks which was passed to Mr. Greenwood, for his paper, and for the large number of excellent drawings and specimens that he had exhibited.

The following paper was then read:—

DESCRIPTION OF A PORTABLE STEAM RIVETTER.

By Mr. ANDREW WYLLIE, of Liverpool.

The Portable Steam Rivetter forming the subject of the present paper belongs to the steam hammer class, and performs the rivetting by a succession of rapid blows. Rivetting by a portable steam hammer is by no means a new idea, and several attempts have already been made to carry it out in a practical manner: to mature such a machine however is not an easy task; and the portable steam rivetter now to be described is the result of many trials, frequent failures, and several improvements. As the portability of the rivetter depends upon its convenience of size and form as well as upon mere lightness, both of these considerations have to be kept in view in its construction; and consequently in irregular work it is not expected that the machine will ever be able to compete with manual labour; but by a simple modification of the steam hammer, the size of the steam rivetter has been so reduced that in straightforward work no more room is now necessary for rivetting by the machine than is required for hand-rivetting.

In steam hammers the piston inside the cylinder is connected by the piston rod to the hammer head, the latter being outside the cylinder and separated from the piston by the cylinder bottom with its stuffing-box; and the piston and the hammer head therefore travel each through the same space in the same time. The total length of a machine so constructed must therefore be equal to at least twice the length of the stroke, together with the sum of the lengths of the cylinder cover, the piston, the stuffing-box, and the hammer head. Moreover in order to apply such a machine to rivetting, it would generally be necessary to use a swage-tool for the head of the rivet,

especially if the head is to be of a snap form ; and this would be an additional length to be added to those already named. The first step in the construction of the present portable rivetter was accordingly to get rid of a greal deal of this length of machine.

Fig. 1, Plate 30, shows a general elevation of the rivetter and dolly in their working position, and Fig. 2 is a transverse section of the rivetter : Figs. 3 to 9, Plates 31 and 32, show the construction of the rivetter to a larger scale.

The rivetter is made with a swage-tool always, whether for flush rivetting or for snap-heads; and this swage-tool A, Fig. 8, is held in the front end of the cylinder B, and forms a loose plug or plunger not connected to the piston ; while the piston itself C is an independent long bolt or hammer of suitable weight, traversing backwards and forwards like a shuttle in the cylinder B, and striking the end of the swage-tool A within the cylinder. By this arrangement the swage-tool or tool-head A remains almost stationary ; and the total length of the machine is reduced to only the length of the stroke of the piston, together with the part struck of the tool-head, the length of the piston, and the thickness of the back cover ; while the length required in an ordinary steam hammer for the stroke outside the cylinder and for the stuffing-box is here got rid of altogether. This is not only a saving of length, but also an economical simplification, and does away with the risk of breaking the bottom of the cylinder by an unobstructed stroke of the hammer ; for the tool-head being entirely loose in the cylinder acts as a safety bottom to the cylinder. In rivetting, the tool-head simply follows the rivet as it is hammered up, and remains in contact with it ; so that the workman has to look at an almost stationary tool-head instead of at a rapidly moving hammer, and he can therefore better adjust the position of the machine to the proper formation of the rivet head.

The principle of the hammer part of the rivetter having thus been arranged, the next point to be determined was the size of the cylinder, so as to render the machine portable and controllable, and of such a size that the workman may be able to hold it in its position independent of its mechanical fixings. In the back stroke of the

piston, the reacting pressure is upon the tool-head; but when the piston is being propelled forwards the reaction tends to push the machine back from its work, and the total amount of this pressure should not be more than the workman can readily withstand, as he might accidentally throw the whole pressure on himself by giving the machine steam when it was not fixed. It might at first be thought that in a horizontal push the force which the workman could exert would not be very great; but as the steam pressure is not continuous, but acting only during the forward stroke of the piston, and as the return stroke occupies probably three times as long as the forward stroke, the workman by a steady pressure of moderate amount can resist a momentary intermittent pressure of nearly four times that amount. The size of the cylinder for the horizontal rivetter, shown in Fig. 1, was accordingly fixed at $1\frac{1}{2}$ inches diameter, which with 60 lbs. steam gives a total pressure of about 100 lbs. on the piston. The stroke of the piston is about 15 inches, so that the full force of the blow will be about 125 foot-pounds; and this, with the hammer piston weighing $3\frac{3}{4}$ lbs., is found to be sufficient to make firm work with $1\frac{1}{4}$ inch rivets. The machine has not been tried on larger rivets.

The tool-head A, Fig. 8, which receives the blow from the piston and communicates it to the rivet, must not be made too heavy, otherwise its inertia would deprive the blow of much of its force. It must also be long enough to follow up the rivet, while still having sufficient length left in the cylinder to serve as a guide. These two conditions are met by making the tool-head hollow towards the piston, as shown in Fig. 8; and its weight is only from $1\frac{3}{4}$ to 2 lbs., or about half the weight of the hammer piston. The piston C has a long tapering end, which enters the hollow of the tool-head and strikes on the bottom of the recess. It was anticipated that the striking surfaces would soon be broken by the rapid blows of hard steel on hard steel; but it is found that the constant presence of steam prevents their overheating and mutual destruction, and in no instance have they been found to fail at present. Their durability however is only a question of time; and to retard the progress of destructive crystallisation, the piston and tool-head are occasionally

annealed by being brought to a red heat and slowly cooled, and then their striking surfaces are tempered in oil.

The face of the tool-head for flush rivetting is made slightly rounded, but nearly flat; for snap-rivetting it is formed into a cup of the required form. It is always easier to make a pan-head by the machine, that is a head which is the frustrum of a cone, than a snap-head, as the sides of the pan-head form a firmer centering for the machine. The tool-head has two or three grooves turned on the inner end for twine packing, as shown in Fig. 8, which is sufficient to withstand the very slight pressure of steam in the return stroke of the piston; the steam port D at the front end is only about 1-100th square inch in area, and the tool-head might therefore almost be left without packing.

In the distribution of the steam, as the piston has no projecting part outside, its motion cannot be made available for working the slide valve by external connections; and the first rivetter was made with inside tappet levers, moved by the piston coming in contact with them. Although these served the purpose very well, it was thought that, as the speed of the piston was sometimes above 2000 feet per minute when it struck the front tappet, such an action would be destructive to the machine, notwithstanding that the movement was effected by a very gentle taper upon the piston. The next machine was therefore made with an inside tappet at the back end only, and with a small steam port at the front end for moving the valve; and the return stroke of the piston being performed at a comparatively low velocity, the inside tappet can be worked at the back end with great accuracy and with little wear. Moreover it is necessary to retain the mechanical movement at the back end of the cylinder, in order to secure the requisite certainty of action for preventing the possibility of the piston ever striking that end of the cylinder.

The slide valve E is a piston valve, and is shown in its two extreme positions in Figs. 8 and 9. In the position shown in Fig. 8 the hammer piston C has uncovered the valve steam port F, and the steam which has been propelling the hammer piston can now act on the piston of the slide valve E, which is thereby moved forwards

into the position shown in Fig. 8, cutting off the steam at G from the chamber H of the back port and opening it to the exhaust K, and closing the front port D from the exhaust K and opening it to the steam G. In this position the steam chamber G has an opening to the front port D through a groove in the side of the slide valve, this groove being partly closed by the small regulating screw I, and the steam is thus admitted slowly to the front of the hammer piston. At the same time the back port chamber H and the back end of the cylinder are open to the exhaust chamber K. As there is then steam pressure on the front of the hammer piston, and a free exhaust behind it, the piston will move towards the back end of the cylinder; but at some distance from the end it comes into contact with the inside tappet J, Figs. 4 and 5, for which a recess is provided in the side of the cylinder, and the piston in passing pushes the tappet into the recess, as shown by the dotted line in Fig. 4. The tappet motion draws the slide valve back, and the openings of the steam passages are thereby reversed, as shown in Fig. 9; and the motion of the piston is changed to the forward stroke before it has come into contact with the back end of the cylinder.

The back port pipe L, Figs. 3 and 5, is the steam way to the back end of the cylinder, and connects it with the back port chamber H of the slide valve casing, Fig. 8. This pipe is screwed steam-tight into the valve casing, and at the back end it is packed with a gland, as shown in Fig. 5, which allows for the expansion of the tube. A separate tube is used for the sake of getting a simpler form for the cylinder casting, and in order to save weight and get a cleaner passage than if it were cast in one piece with the cylinder.

The back end of the hammer piston C, Fig. 8, is made of a curved shape to ease the shock of the blow upon the inside tappet J, Fig. 4. At the front end the body of the hammer piston in the first rivetter had longitudinal channels made in it, extending so far back that when the piston advanced to the fullest extent in following up the tool-head the body of the piston should not close the front steam port D: these channels were adopted in place of turning down the entire body of the piston, in order that the full

length of bearing of the piston in the cylinder might be preserved. In the improved construction of the rivetter however, shown in the drawings, the necessity for these channels is obviated by extending the front steam port D far enough forwards, as shown in Fig. 8, so that it is never entirely closed by the body of the piston.

The steam stop-valve is a small grid valve, with a spring to keep it on the face, and a spiral spring to close it; or a cock with a spring to close it. It is in a casing at the side of the steam chamber of the slide-valve, and is opened by a cord extending to one of the back handles M at the end of the cylinder. Any difference in the amount of opening of the steam stop-valve affects only the forward stroke of the piston and the force of the blow, the velocity of the back stroke being regulated by the set screw I in the steam groove of the slide-valve, Fig. 8, which determines the rapidity of the blows without altering their force. The steam is conveyed to the rivetter by a six-ply flexible tube of $\frac{3}{4}$ inch bore, with brass nozzles of $\frac{1}{2}$ inch bore. The exhaust pipe is $\frac{3}{4}$ inch bore at the nozzle, and a short length of india-rubber pipe of 1 inch bore is attached to carry the waste steam away.

The horizontal rivetter shown in the drawings consists of two parts, the rivetting cylinder and the holder-up: when in operation these two portions are locked together through the next rivet hole, as shown in Fig. 1, and in this form the portable steam rivetter is therefore called the "locking machine," to distinguish it from the other forms of the machine which are either permanently coupled or permanently separate. The locking pin N is attached to two short studs cast upon a nozzle O, Fig. 8, which is screwed on the end of the rivetting cylinder, being held from turning by the spring bolt P, Fig. 3, engaging in one of the notches Q upon the nozzle. The foremost of these studs R is mounted with a hollow screw and key S for adjusting the position of the locking pin to suit the gauge of the rivet holes; the other stud is a guide for the inner end of the locking pin. The locking pin is 5-8ths inch diameter, of steel, and the socket in which it is fixed forms a large shoulder, as shown

in Fig. 8, for butting to the plate that is being rivetted: this shoulder is so much in advance of the end of the tool-head that sufficient room is left for the projection of the head of the rivet, as seen in Figs. 1 and 10. On that part of the locking pin which is on the other side of the plates, there are a number of ratchet teeth, Fig. 13, and these lock with a catch T on the holder-up, by which means the two portions are held together during the operation of rivetting. The locking pin is made in two pieces, a head with two eyes which go on the two studs of the rivetting cylinder, and the pin itself which is cottered into this head, so that either a larger or smaller pin can be used as required.

The blow of the portable steam rivetter is so powerful that for horizontal rivetting a common dolly cannot be employed, as the rivet would never be brought up in the head. A spring dolly is therefore used, as shown in Figs. 10 to 13, Plate 33, and its action has been found very satisfactory. The dolly is in a spring box made of 3 inch boiler tube, on the front of which are the eye and locking catch T for connecting the dolly to the locking pin N of the rivetter. By entering the eye on the locking pin and forcibly pushing the dolly along the pin, the spring would be compressed and the catch T would engage in one of the teeth of the pin. But it would be very difficult to run the dolly up perfectly fair on the pin, and the locking catch might not engage securely with the tooth, and might be only on the point of the tooth, in which case the dolly would be driven off by the first blow of the rivetter, and the rivet would not be brought up in the head. To obviate this the dolly is made with a compression notch U at the back end, and a spring detent V in one of the handles W; and the workman holding the dolly by both handles places it on the ground, and by a sudden jerk compresses the dolly spring until the detent V lays hold of the notch and the compression of the dolly is thereby retained. The dolly is now lifted and entered on the locking pin, and the rivet is inserted and pushed home by the dolly, and the locking catch T lays hold of one of the teeth of the locking pin; as there is now no strain on the dolly, the catch T is not prevented from entering to the bottom of the tooth so as to obtain a secure hold of the locking

pin. By then turning the detent handle W, which is screwed into the dolly cap, the detent V is withdrawn; and the dolly being released, as shown in Fig. 10, presses upon the rivet with almost the full compression got by jumping it together on the ground.

During the rivetting the workman has only to keep the dolly true on the rivet head by a slight pressure sideways, and the strongly compressed spring causes it to press with great force on the rivet, and makes very sound work. When the rivet is finished, the locking catch T is disengaged by means of the lever X, and the dolly being released resumes its original condition, as shown by the dotted lines in Fig. 10. With flat-headed rivets the dolly is merely turned round on the locking pin, and the catch T is thereby thrown out of the tooth which is only on one side of the pin. The dolly is then removed from the locking pin for the purpose of being compressed again; the workman on the rivetting side has at the same time removed the rivetter to the next hole, and when the dolly is lifted up the locking pin is ready for it, and the same process is repeated.

It was originally intended to support the portable rivetter by a lanyard with sufficient slack to allow of a great range of the machine. Where it is convenient to have this it would no doubt be an advantage, as the lanyard would not require to be shifted or altered in length oftener than about once an hour for horizontal seams. It would be attached to the front of the machine, and should be of such a length as to suspend the machine 6 or 8 inches below the rivet holes, so that the workman would have to depress his end of the rivetter sufficiently to tilt up the point of the locking pin to the rivet hole, when the machine could be pushed home. It is found however that the rivetter can be worked without a lanyard, without much inconvenience to the workman. When the rivetter and dolly have been locked together, the workman is relieved from all the weight; and it is only in shifting from hole to hole that he has to carry the machine, which is easily lifted with one hand at the back end and the other at the locking pin handle S, Fig. 1. In the first machine there were handles at the front end also, but these were not needed and have been discontinued.

In Fig. 14, Plate 34, is shown an elevation of a vertical coupled rivetter, in which the rivetting cylinder B and the dolly Y are permanently coupled together by the coupling Z. This form of the rivetter is particularly suitable for rivetting ships' frames lying horizontally on the ground; and in this case the rivetting cylinder B is below, and the dolly Y at top. For shifting the machine when the rivet is completed, the dolly is compressed by a jerk as before, and the compression is retained by the detent until the machine has been removed to the next hole and the rivet inserted, when the detent is withdrawn, and the dolly holds up the rivet against the blows of the rivetter.

In the horizontal locking rivetter, the weight of the rivetter itself and locking pin is 45 lbs., and of the holder-up 34 lbs. The vertical coupled rivetter is a few pounds heavier, the holder-up not being altered in weight.

Mr. Wyllie explained that the portable steam rivetter described in the paper just read was the invention of Mr. J. Mc.Farlane Gray, who was present at the meeting and had brought over one of the rivetters, which would be worked with steam during the conversazione to be held in the International Exhibition that evening, when the members would have an opportunity of witnessing its actual working.

Mr. Gray exhibited one of the portable rivetters, and showed the mode of bringing it up to the work to be rivetted. He explained that the rivetter required no lanyard or other arrangement for supporting it in work, as its weight was carried whilst rivetting by the locking pin inserted through the adjacent rivet hole; and it was easily lifted from hole to hole by the two attendants, one of

them shifting the dolly while the other shifted the rivetter itself: the screw and key gave the means of altering the distance of the locking pin from the rivetter to suit the pitch of the rivet holes. With 60 lbs. steam the hammer piston gave about 300 blows per minute. He exhibited a specimen of plates rivetted together by the machine with $1\frac{1}{4}$ inch rivets, and afterwards slotted down the centre of the rivets, to show how completely the holes were filled by the rivets.

The President enquired how the working of the rivetter would be managed in rivetting at a ship's side, where there would be little room to work in.

Mr. Gray replied that the man with the rivetter stood on a platform outside the ship's side, and the other attendant with the dolly on a platform inside, where the rivets were to be put in. The locking pin of the rivetter having been passed through the hole next to the one to be rivetted, and the dolly entered on the pin, when the hot rivet was inserted into the hole, the compressed spring of the dolly was liberated by the man on the inner side, holding up the rivet true and firm in the hole; and then the other man by pulling the string attached to the steam valve turned on the steam, and the rivet head was immediately completed by the blows of the rivetter. The locking pin was then instantly released by merely turning the dolly partly round upon the pin if the rivet head was flat, or by releasing the locking catch by the lever if the dolly had a cupped die; and while the rivetter and locking pin were shifted to the next hole by the man outside the ship, the other attendant inside compressed the dolly spring again, and was ready to slip it over the locking pin as soon as the latter was put through the next rivet hole from the outside. This was done so quickly that the shifting of the rivetter and dolly did not occupy more than about 8 seconds, and the act of rivetting occupied about 7 seconds, making about 15 seconds total for each rivet. He then showed to the meeting the facility with which the rivetter and dolly were coupled and uncoupled by the locking pin, and the rapidity with which they were shifted from hole to hole in a plate.

The PRESIDENT asked whether it was expected the rivetter could be worked as fast as to take only about 15 seconds for each rivet in ordinary working, as it seemed doubtful whether the men would be able to stand that rate of work as a regular thing.

Mr. GRAY replied that the machine was guaranteed to do one rivet per minute easily in ordinary straight work, and two or three per minute could be put in if there were any hurry about the work.

Mr. J. MURPHY enquired what was the comparative speed of rivetting by the machine as compared with hand rivetting.

Mr. GRAY replied that in rivetting straightforward work such as the sides of the Britannia tubular bridge one of these machines could put in a thousand rivets in a day of ten hours, being at the rate throughout of one rivet in 36 seconds. In a special trial of speed with the machine he had himeslf put in fifteen rivets in 3 minutes and 35 seconds or at the rate of 14 seconds per rivet; and on another occasion he had put in three rivets in 26 seconds by the machine. There was therefore no doubt that the rivetting could be done by the machine considerably faster than by the most expeditious hand work. The men who had worked the machine much preferred using it to being either the holder-up or the rivetter in ordinary hand rivetting; and the construction of the spring dolly caused the shock to the man holding up the rivet to be much less than in hand rivetting.

Mr. J. RAMSBOTTOM enquired what was the weight of the hammer piston in the rivetter.

Mr. GRAY replied that the hammer piston was $3\frac{3}{4}$ lbs. weight.

Mr. C. COCHRANE enquired what extent of area could be worked over conveniently with the steam rivetter without having to shift the steam pipe connections. He supposed a flexible steam pipe would be necessary for enabling the machine to work over a considerable area.

Mr. GRAY explained that the first and the last lengths of the steam pipe conveying the steam to the rivetting machine were flexible, and each about 10 or 12 feet long; the rest of the steam pipe was only $\frac{3}{4}$ inch gas pipe, which could be carried to any

distance that might be desired for conveying the steam from a stationary boiler; or a portable boiler with a shorter length of steam pipe might be employed if preferred.

Mr. J. Fernie remarked that he remembered a portable steam rivetter had been constructed some years ago by Mr. Naylor, and he thought it would be very useful if they could be informed what had been the difficulties that had been met with in that machine.

Mr. W. Naylor said he had found many difficulties in working out the portable steam rivetter, and had not been able to succeed in bringing it to what he could consider a practical success; and only two or three of the machines had been constructed and put to work. One practical difficulty, which he thought would be found also with the machine described in the paper as well as with any other steam rivetting machine, had arisen from the rivets not being always perfectly at right angles to the plate: if the rivet came exactly square through the plate, the hammer might then strike it true and bring it home with a fair head; but if the rivet did not come exactly square through the plate, it would not be truly in line with the stroke of the hammer, and the hammer might turn it to one side and form the rivet head on one side. He had had one machine made with the hammer on a universal joint so as to move round, in order that if the rivet came through the hole not quite square the hammer could be turned so as to hit it fair and bring it straight again. There was also a practical difficulty in using a machine for such work as iron shipbuilding, where one portion of the ship's side was vertical and other portions slanting, and the bottom part was particularly difficult to get under with a machine. With the smaller rivetting machine that he had made the rivet was held up by a man with a lever dolly in the ordinary way; but with a larger machine he had employed a small steam cylinder for the purpose. The great difficulty however was to get rivetters who would use the machine, as the men thought they would do the work much better without the machine, and so save all the cost of it. If he had himself had the entire management of the work in all respects, he might perhaps have succeeded in performing it with

the machine: but he had been satisfied by the experience which he had had that under ordinary circumstances he should not be able to make the machine a commercial success so that it could advantageously compete with hand labour. There was no doubt that a portable steam rivetter would be a very valuable tool, if the difficulties that had been encountered could be overcome, so that the machine could be brought to bear practically for rivetting.

Mr. Gray said he had contemplated the difficulties that had been mentioned; and as regarded that arising from oblique position of the rivet in the rivet hole, he did not think it existed to such an extent with the rivetter described in the paper as had been supposed, because the steam rivetter was intended to be used with machine-made rivets, which would have the rivet head truly square with the bolt. If therefore a rivet came through not square with the plate, it was not the fault of the rivet, but showed that the holes in the plates were not fair. The steam rivetter however acted with such force that the rivets were not required to be the full size of the holes, but considerably smaller rivets could be used, which were still made to fill the holes completely by the compression produced by the machine; and accordingly in working 1 inch holes with $\frac{3}{4}$ inch rivets the machine made a sound job of the rivet and filled the hole up at once. This allowed $\frac{1}{4}$ inch of slant in the hole, while still keeping the rivet square to the plates. Moreover the spring dolly for holding up the rivet pressed with very great force upon the rivet, so that the rivet must come through the plate square or very nearly square. Even if the holes were tight however, and the rivet got a little slant to one side, the machine had sufficient play to allow for this, as the locking pin passed loose through the adjacent rivet hole, which had the same effect as a universal joint in allowing of the amount of deviation that was needed to perform ordinary rivetting; while the rivetter itself, being only about 45 lbs. weight, admitted of being turned about almost as easily as a hammer. It had thus the advantage of affording as great facility for straightening a slanting rivet as in hand rivetting, provided of course that the workman noticed the rivet was slanting.

The application of the machine to snap rivetting was perhaps not entirely satisfactory at present, but it was very much better than he had anticipated; in the first trials indeed snap rivetting had been given up as hopeless with the machine, and it was not until lately that the machine had been tried again for the purpose with the ordinary round snap-heads. The machine had been employed with success upon pan-head rivets, which could be got hold of better by the die of the rivetter, and twisted by it slightly to one side or the other: but it was now found that even the snap-heads could be easily managed, and this was to be attributed he thought to the efficiency of the holder-up, which had been improved since the former trials.

With regard to the difficulties of getting the steam rivetter introduced on account of the prejudices of the men, he might mention that the first of the machines which had been made had been sent down to Messrs. Napier's works at Glasgow to be employed for rivetting up ships' frames lying horizontally in the yard; it was one of the vertical coupled rivetters, which was the form first made, and it was guaranteed to put in one rivet per minute in regular work. In the trial of it at starting he had himself put in fifteen $\frac{7}{8}$ inch rivets in 3 minutes and 35 seconds, which was considered so decided a success that two of the machines were ordered instead of one. At the same time he was urged to modify the construction in such a manner as to render the machine capable of being employed horizontally as a portable rivetter, for rivetting the ships' sides &c., because it was not worth while to use the vertical rivetter until the other form had been matured and made practically successful, so that the machine might be relied upon to be capable of doing a great part of the work at present performed by hand rivetting. He had accordingly completed the horizontal rivetter in the form described in the paper, which was sufficiently matured to be practically available and commercially profitable; and men were now ready to go out with the machine and undertake rivetting with it at such a cost as would make it well worth while to employ the machine in place of hand rivetting.

The PRESIDENT observed that the experiment referred to at his works with the first rivetter had given great satisfaction, as had been stated; but there had not been opportunity at present for putting to work the two new machines that had been obtained.

Mr. J. MURPHY considered the portable steam rivetter now described was a most valuable addition to the number of rivetting machines already existing, and thought it would be particularly useful in plating ships, where it was necessary to go to some height from the ground. The ordinary rivetting machines at present employed were of such a ponderous construction that they could not be moved, and the work had therefore all to be brought to them. The great advantage of the new machine was that it could be taken to the work; and from its portability and the simplicity of its construction he thought the objection of the men to using it would soon be got over. Even if the present rivetters refused to work with the machine, other men might be expected be got to use it with a little teaching; and he enquired whether it was necessary to employ skilled workmen to work the machine, or whether unskilled hands could not readily learn to use it. The same objections might be made to sawing and planing machinery, or to any machinery intended to supersede manual labour; but the use of such machines had long been successfully established notwithstanding all such objections.

Mr. GRAY said there would be no difficulty in employing unskilled labour for working the machines; if there were half a dozen machines to be worked at one place, one mechanic would be required who understood them and could keep them in order, while any intelligent labourer could work the machine. The construction of this rivetter was so simple that unless the parts were broken they could not be put together wrong; and duplicates were supplied of the working parts, to provide against breakage. If the ordinary large rivetting machines had proved a commercial success, he thought that ought equally to be the case with the new portable rivetter, because he was satisfied that by means of the portable machine more work and of equal quality could be done with the same number of men and at less than half the expense

for machinery. For a fixed rivetting machine required one man at the crane for lifting the piece of work to be rivetted, another man to guide the work, a third to supply the rivets to the machine, and a fourth to work the machine. If the same number of men were employed with the portable rivetter, two to each rivetter, they would be capable of working two of the rivetters, the cost of which would be less than half that of a fixed machine, while he doubted whether any fixed machine could put in as many rivets in a given time as could be done by two of the portable rivetters. The principal use of the portable rivetter was for such work as the Britannia tubular bridge, in which it could perform the whole of the rivetting; and if in shipbuilding, where a great proportion of the surface was slanting, some places were met with where the machine would not be convenient to use, he did not think that constituted an objection to its employment for the general rivetting work of the ship. The case of the portable rivetter was in fact very similar to that of the sewing machines now so largely employed, which were used with great advantage for a long run of straightforward work, but left a few special parts to be finished by hand work.

Mr. J. Whitley enquired what was about the cost of the portable rivetting machine.

Mr. Gray replied that the cost of one of the rivetters complete with a set of duplicates was about £60, but they were expected to be less expensive when they had come into general use.

Mr. J. Murphy enquired what was the relative cost of rivetting by the machine and by hand labour.

Mr. Gray replied that the men who had had experience of the working of the portable steam rivetters were willing to go out with the machines and keep them in order and to do work with 1 inch rivets for a payment of 1*s.* per hundred rivets; and there would also be the cost of a man to shift the dolly for holding up the rivets, and two boys in attendance, making the whole cost not more than 3*s.* per hundred for 1 inch rivets; and at this rate of payment the men expected to double their present wages. The cost of rivetting similar work by hand was about 12*s.* per hundred rivets.

The President enquired whether there had been any failure yet of any of the working parts in the trials made with the rivetter.

Mr. Gray said that the parts which were expected to wear out first were the piston and the tool-head, as these had all the work upon them in rivetting. In order to test the durability of these parts, one of the rivetters had been put to work with only a small piece of hard steel between the rivetter and dolly, delivering its full stroke on the dolly, and hammering away at the rate of 300 blows per minute without any intermission: after working for about fifteen hours the compression catch piece at the back end of the dolly dropped off, a part not then in use but shaken off by the mere shock of the blows. In actual work this shock was either absorbed almost entirely by the plates, or was transmitted through a hot rivet, and therefore had not this destructive effect. The experiment was continued until the piston was broken across at a packing groove, after having given about 400,000 blows. The pistons were now made without any grooves and were therefore more durable. The tool-heads were now the first parts to give way, and required to be renewed as in any other rivetting machine. The pistons and tool-heads were easy to replace, and duplicates of them were supplied with each machine.

The President moved a vote of thanks to Mr. Wyllie and Mr. Gray for the paper, which was passed.

The following paper, by Mr. Charles Hodgson, of Portarlington, Managing Director of the Derrylea Peat Works, communicated through Mr. G. Arthur Waller, was then read:—

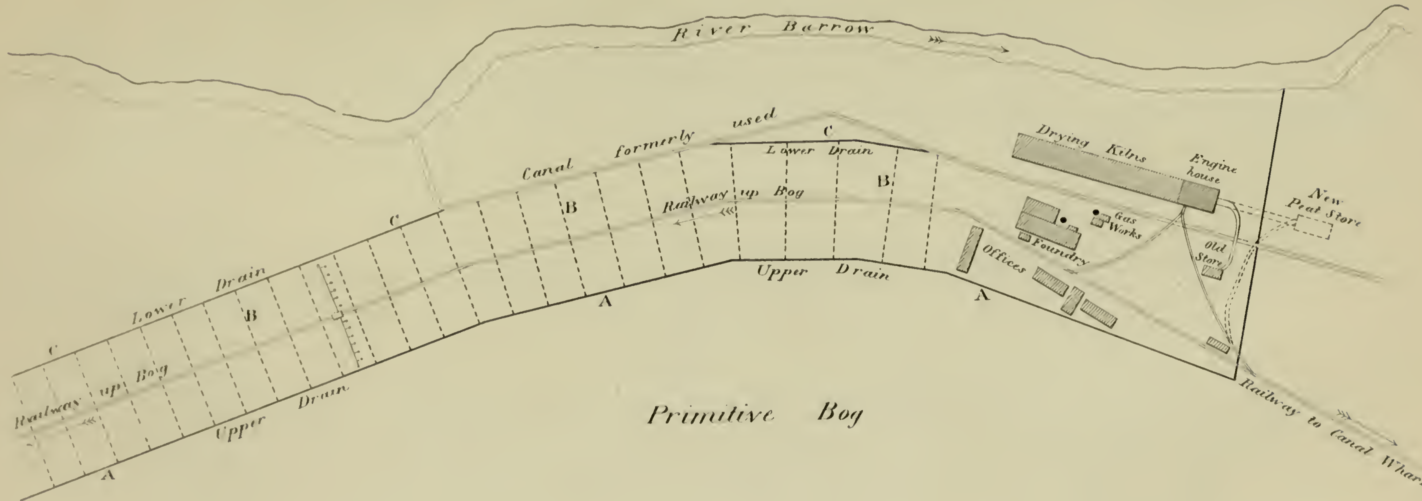
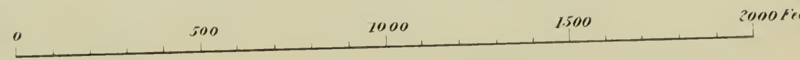


Fig 1. General Plan of Derrylea Peat Works.

(Proceedings Inst M E 1865 Page 147.) Scale 1/6000th



COMPRESSED PEAT FUEL

Plate 36.

Travelling Girder for dragging the Harrows over the Bog.

Fig. 2. *Side Elevation.*

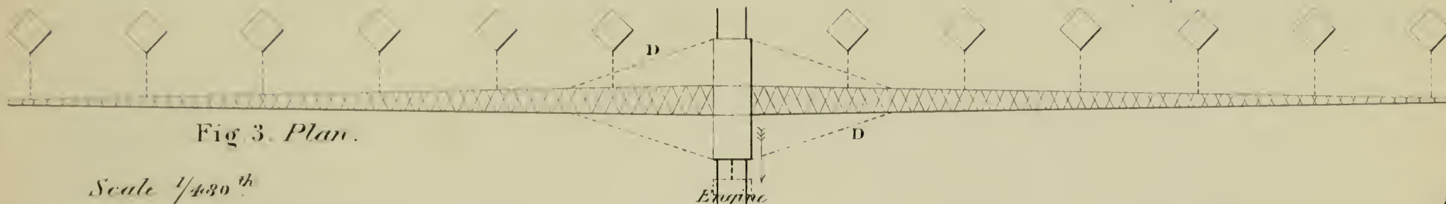


Fig 3. *Plan.*

Scale 1/480th

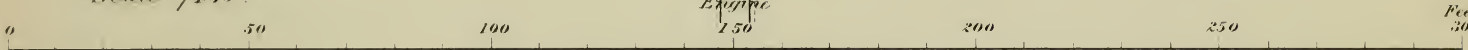


Fig. 4. *Elevation of Girder at centre.*

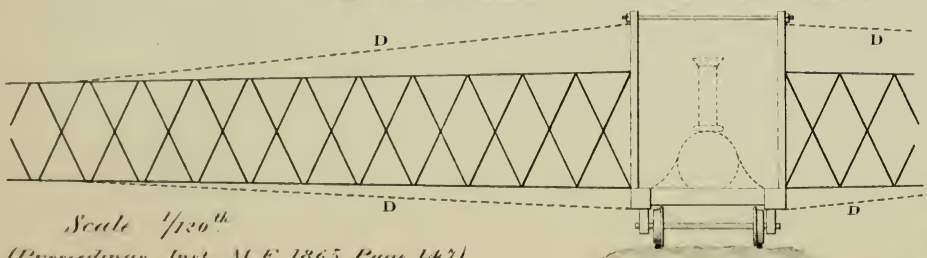
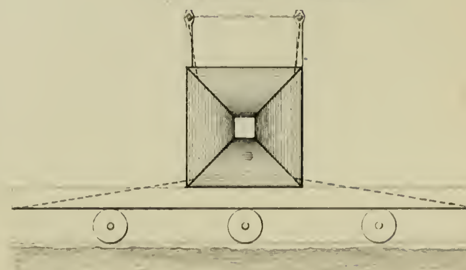


Fig. 5 *End Elevation.*



Scale 1/120th

(Proceedings Inst. M. E. 1865. Page 147)

COMPRESSED PEAT FUEL.

Plate 37.

Fig. 6 *Side Elevation of Drying Kilns and Engine Room.*

Fig. 7. *Transverse Section.*

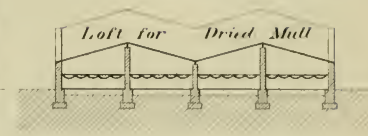
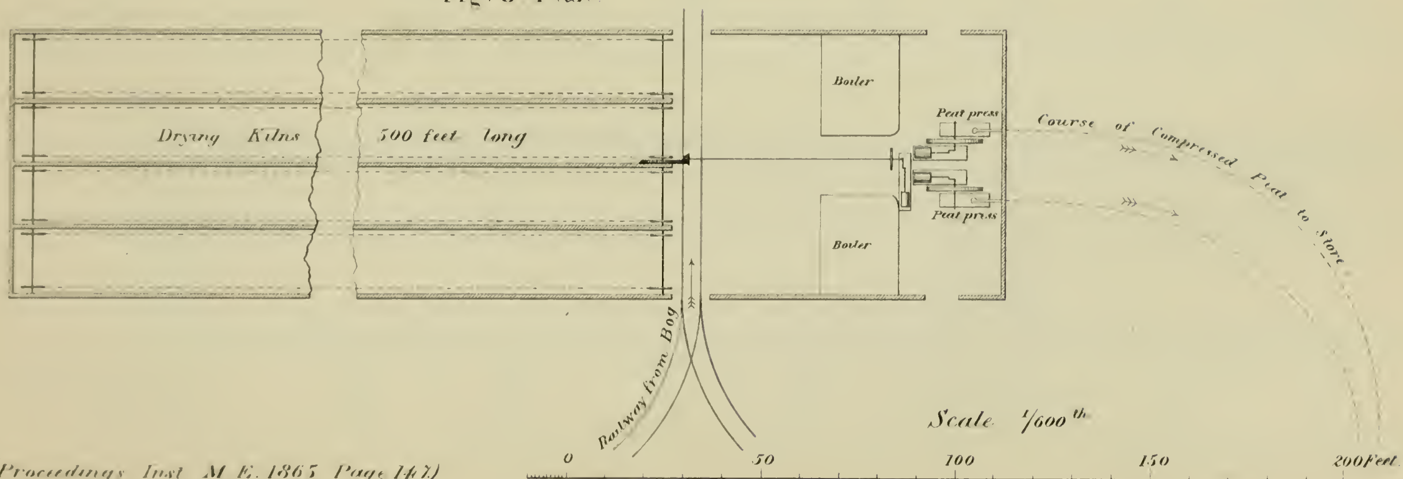


Fig. 8 *Plan.*



(Proceedings Inst. M. E. 1865 Page 147.)

COMPRESSED PEAT FUEL.

Plate 38.

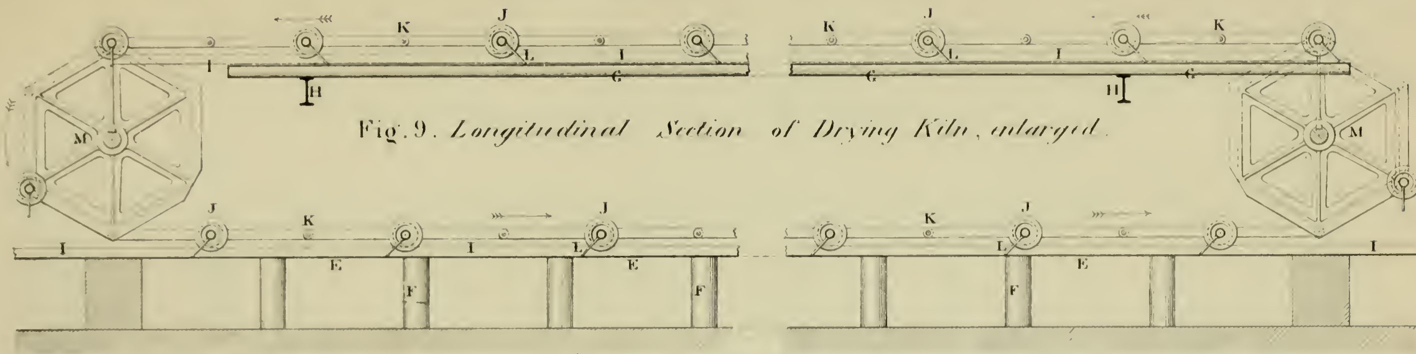
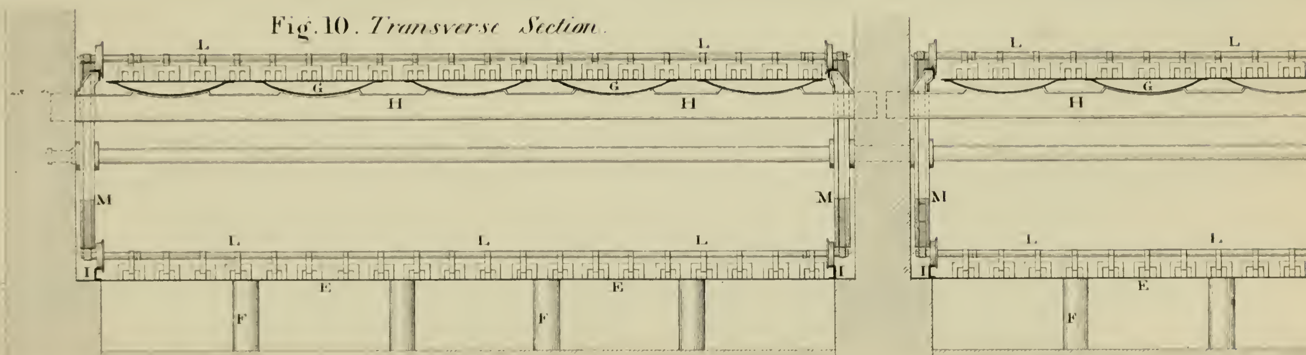


Fig. 9. *Longitudinal Section of Drying Kiln, enlarged.*

Fig. 10. *Transverse Section.*



(*Proceedings Inst. M. E. 1865. Page 147.*) *Scale 1/50th*

0 5 10 15 Feet.

COMPRESSED PEAT FUEL.

Plate 39.

Fig. 11. *Transverse Section of Steam Floor, enlarged.*

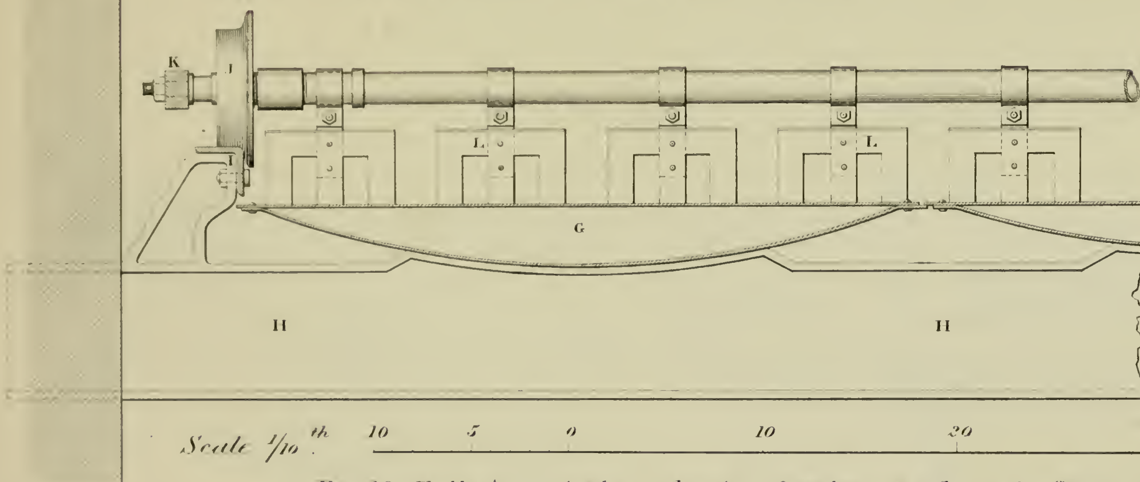


Fig. 12. *Longitudinal Section.*

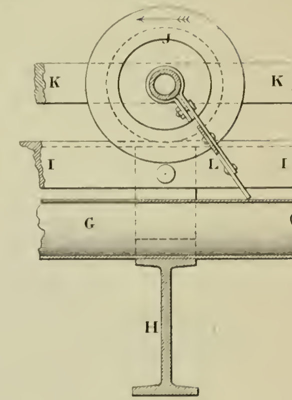
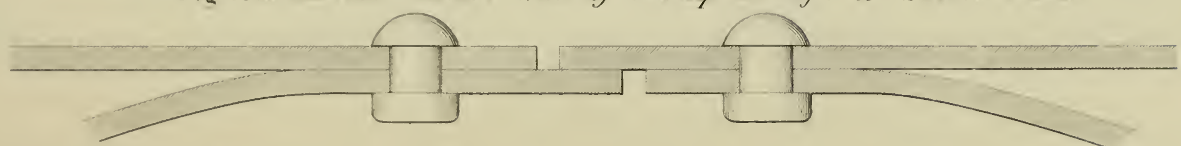
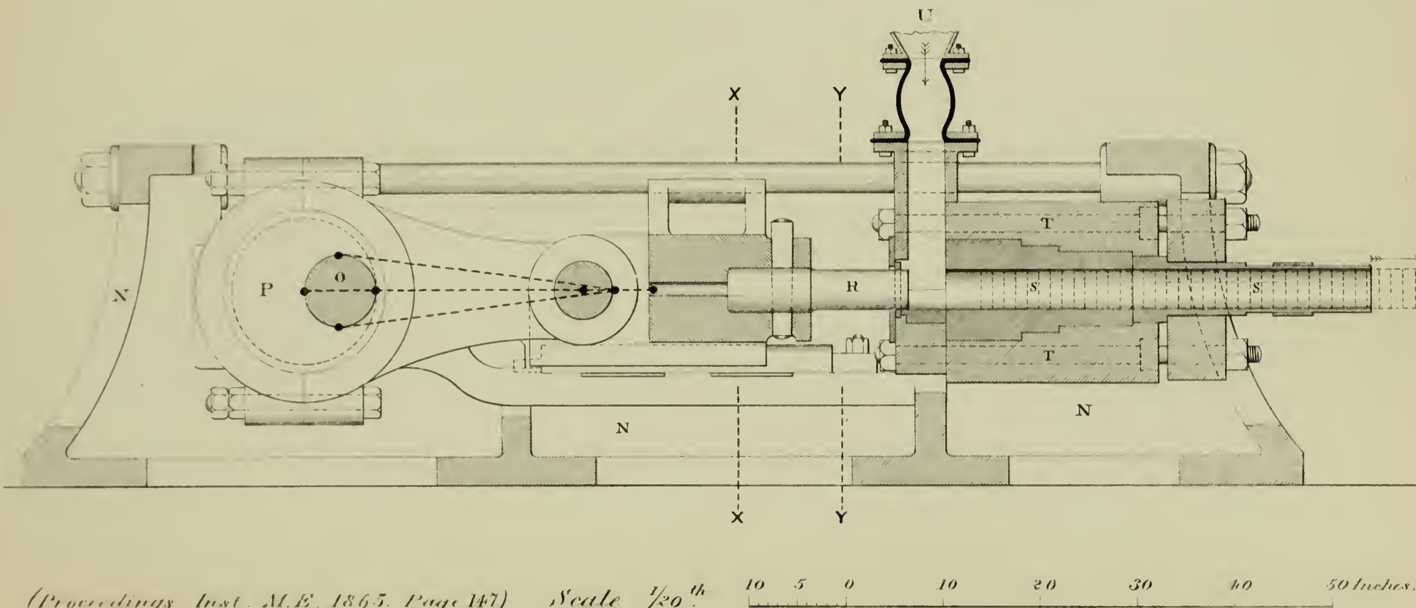


Fig. 13. *Full-size Section showing Overlap at edges of Steam Tables.*



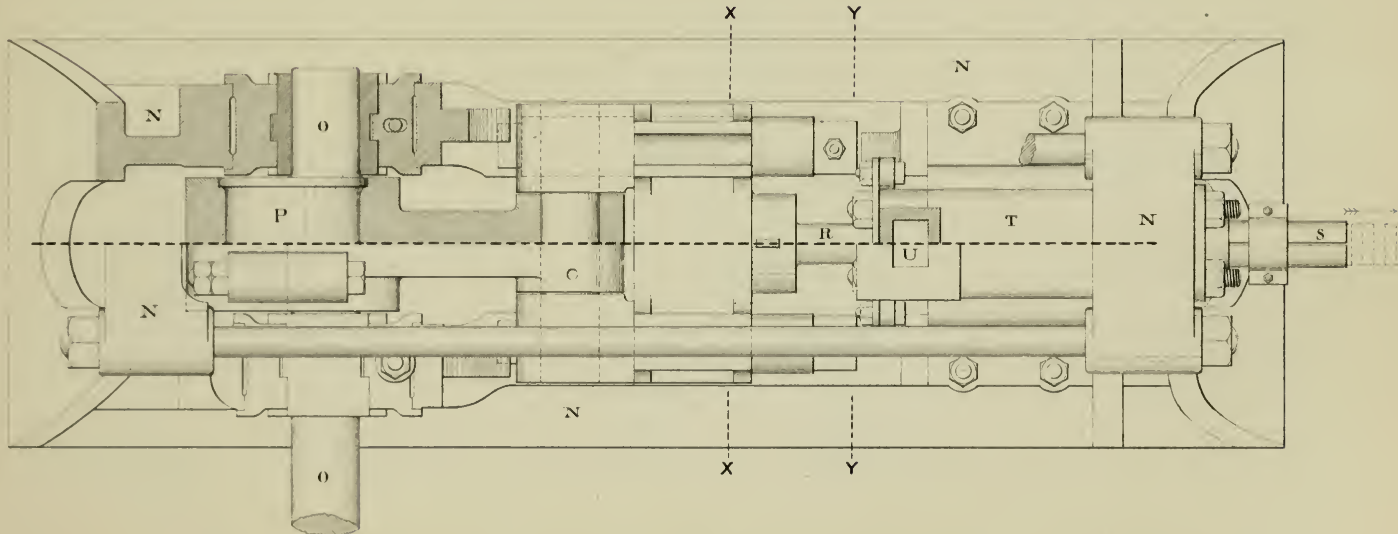
(Proceedings Inst. M.E. 1865 Page 147)

Fig. 14. *Longitudinal Section of Peat Press.*



(Proceedings Inst. M.E. 1865. Page 147) *Scale 1/20th.*

Fig 15. *Plan of Peat Press, partly in Section.*



(Proceedings Inst. M.E. 1865. Page 147) *Scale 1/20th.* 10 5 0 10 20 30 40 50 Inches.

COMPRESSED PEAT FUEL.

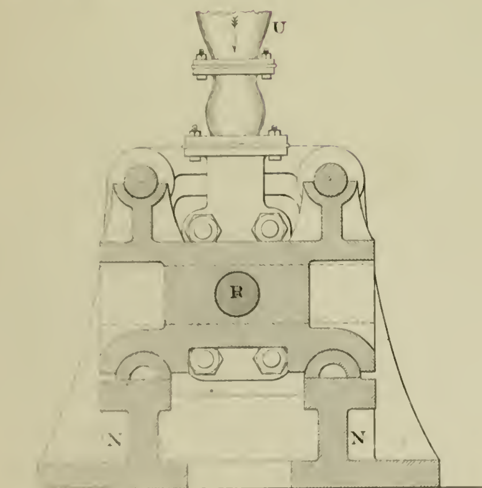


Fig 16. *Transverse Section of Peat Press at* XX *(Figs. 14 and 15.)*

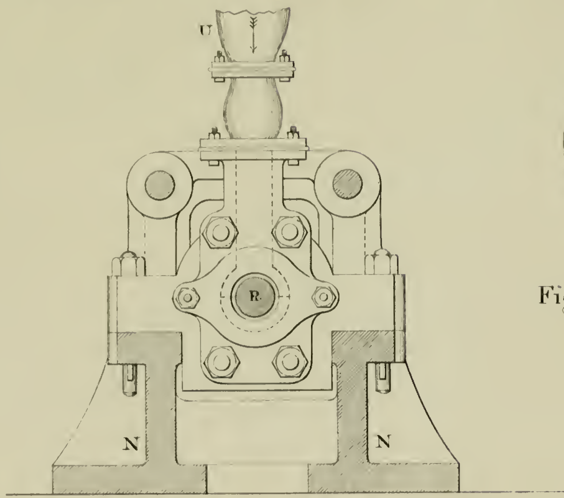


Fig. 17. *Transverse Section of Peat Press at* YY *(Figs. 14 and 15.)*

Fig. 18. *Plan of Tightening Clamp on nozzle of Tube.*

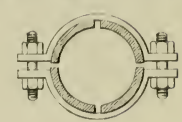


Fig. 19. *Transverse Section of nozzle.*

Scale 1/10th

Scale 1/20th

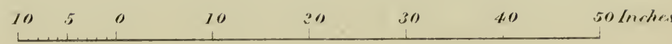
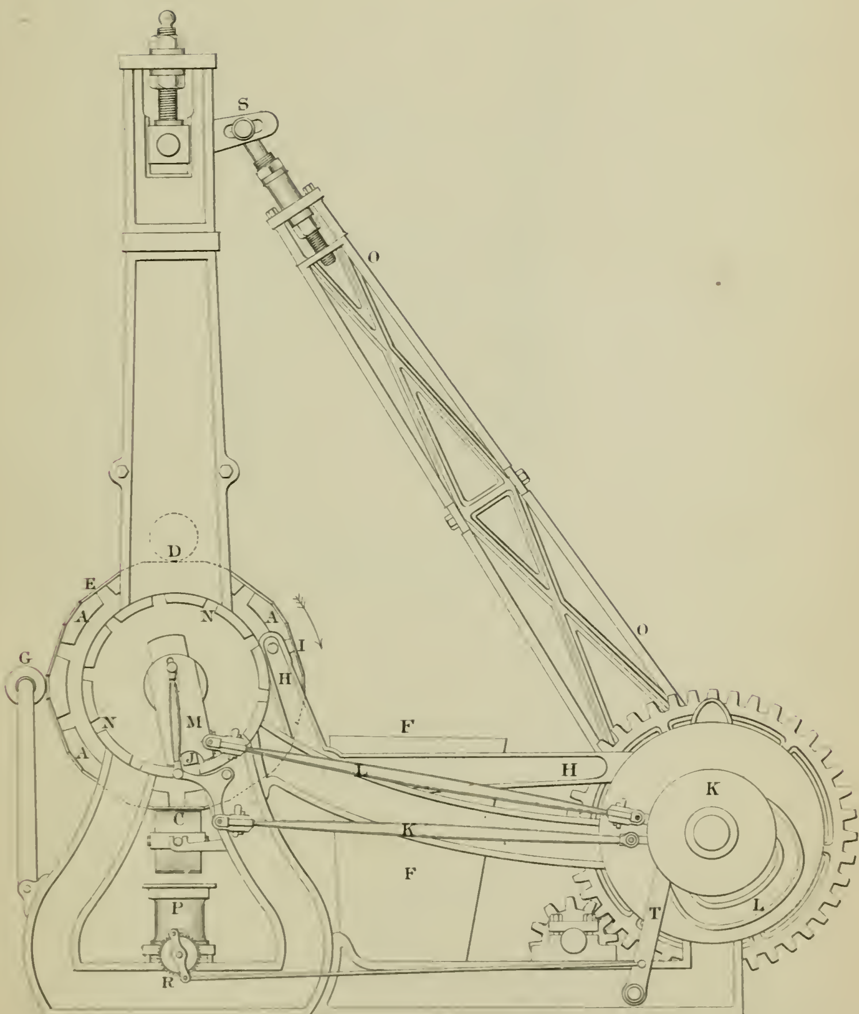


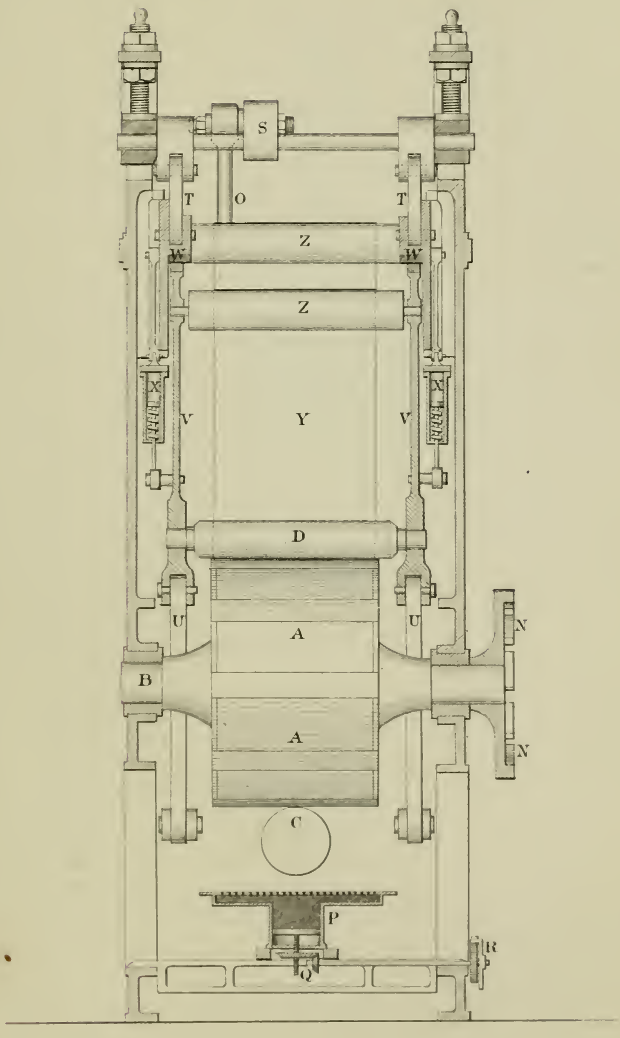
Fig. 1. *Side Elevation.*



(Proceedings Inst. M.E. 1865. Page 166) *Scale 1/24 th*

10 5 0 10 20 30 40 50 60 70 Inches.

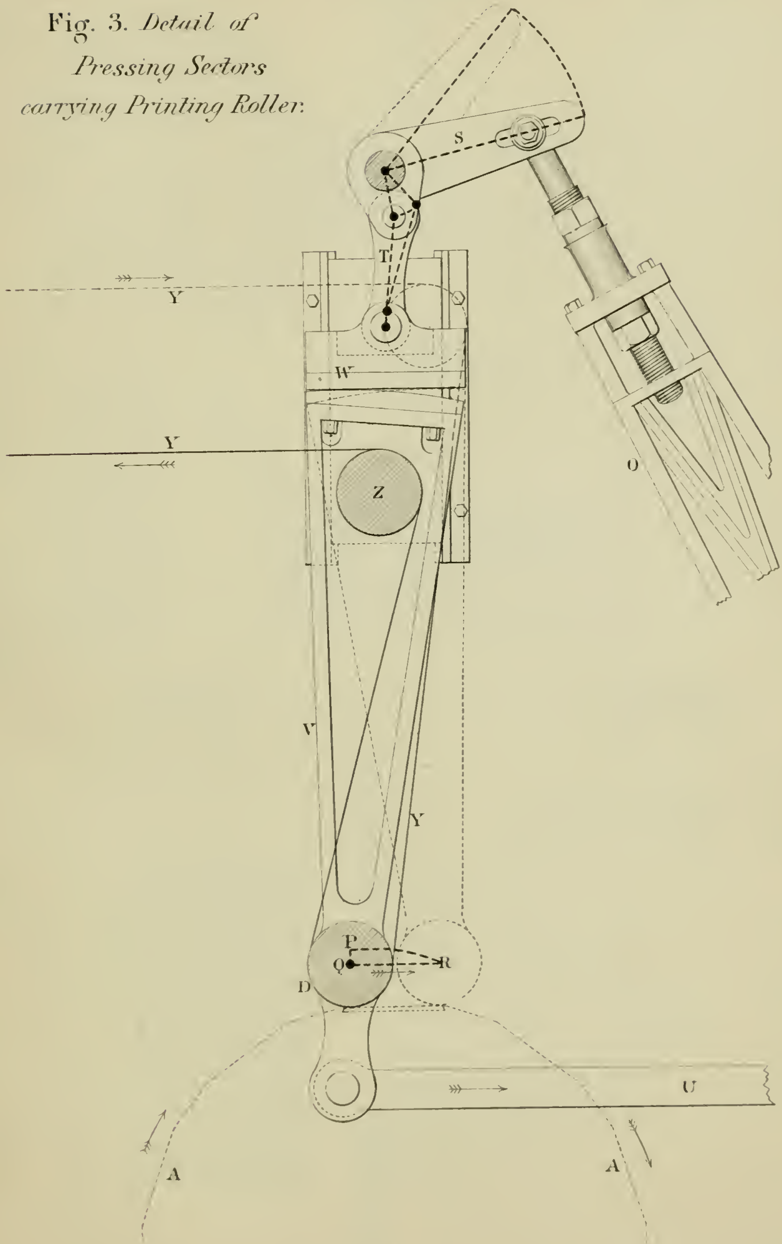
Fig. 2. *Vertical Section.*



(Proceedings Inst. M. E. 1865. Page 166.) *Scale 1/24th*

10 5 0 10 20 30 40 50 60 70 Inches.

Fig. 3. *Detail of Pressing Sectors carrying Printing Roller.*



(Proceedings Inst. M.E. 1865. Page 166) *Scale 1/12th*

10 5 0 10 20 30 *Inches.*

BANK-NOTE PRINTING MACHINE.

Detail of Inking Roller, for inking engraved plates upon the Polygon.

Fig. 4. *End Elevation, showing Roller raised for inking the Polygon.*

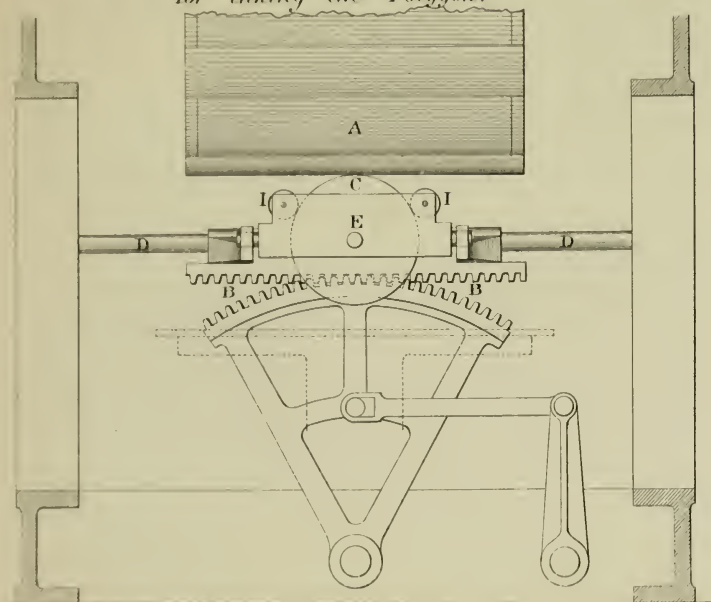


Fig. 5. *Side Elevation, showing Roller raised for inking the Polygon.*

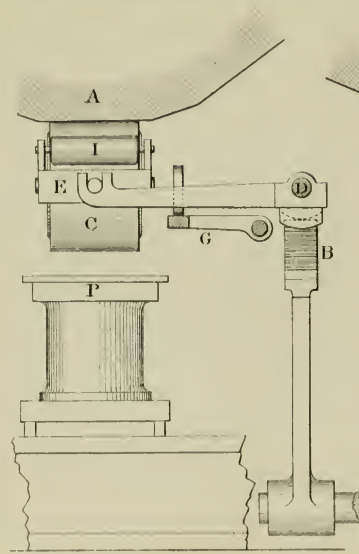
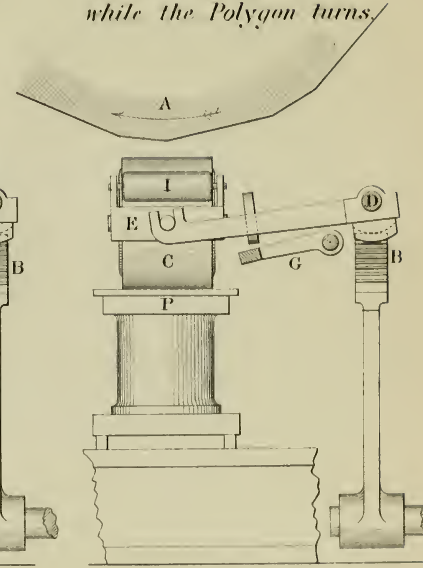
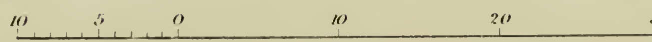


Fig. 6. *Side Elevation, showing Roller lowered for taking up Ink, while the Polygon turns.*



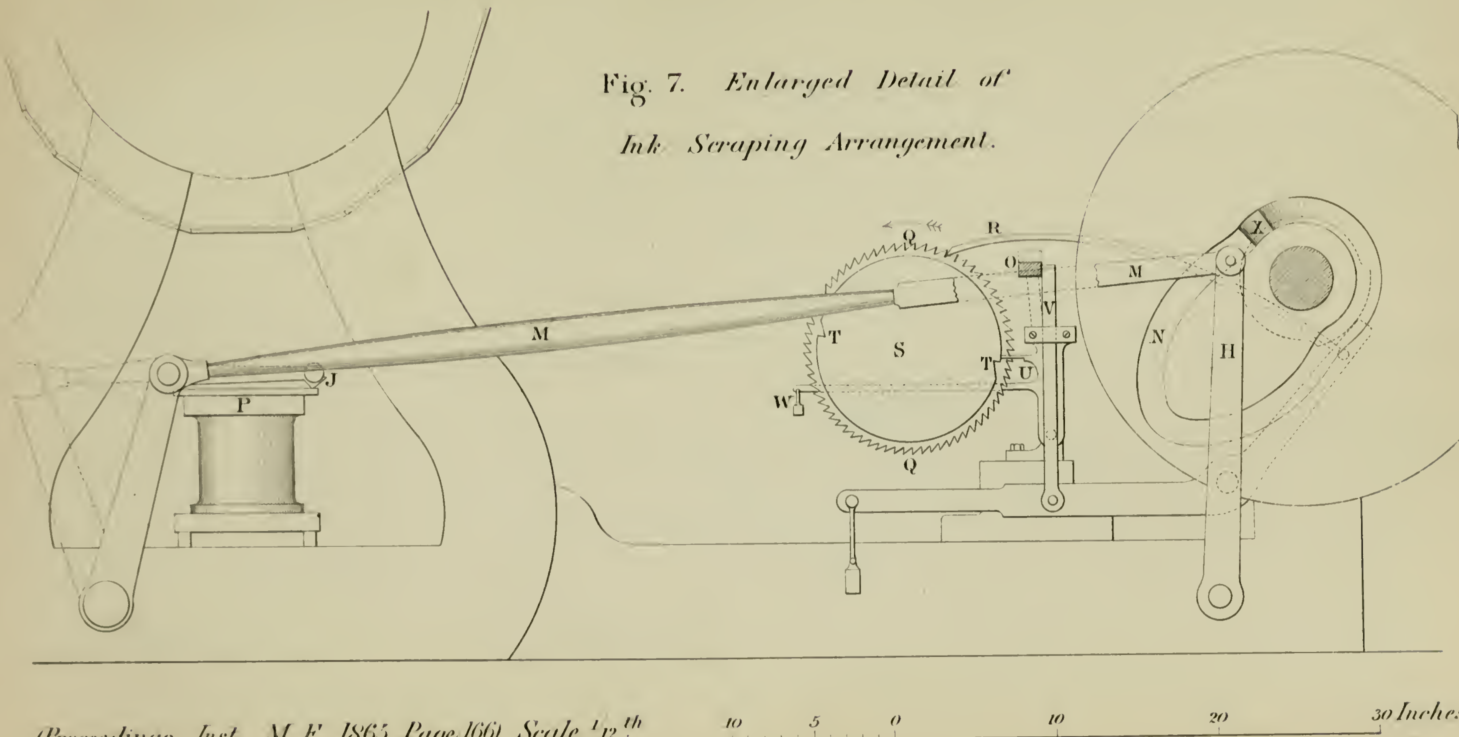
 Scale 1/12th



BANK-NOTE PRINTING MACHINE.

Plate 47.

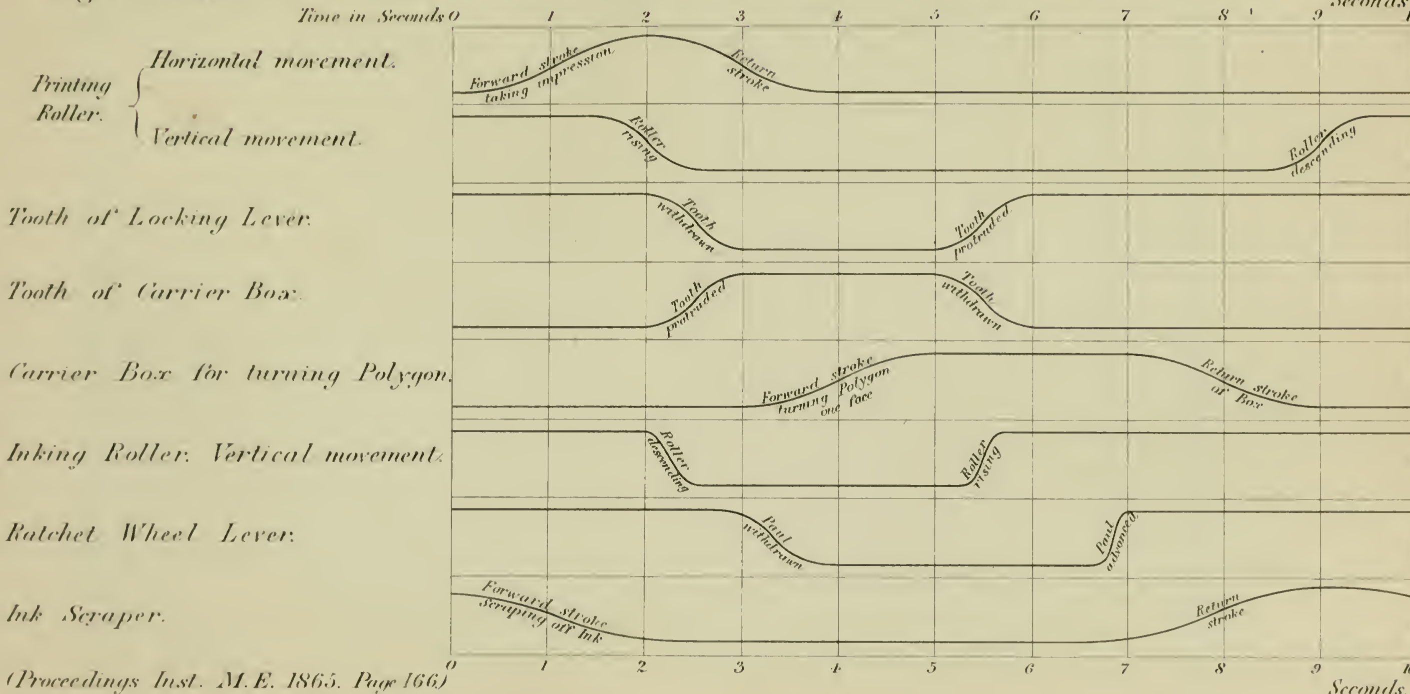
Fig. 7. *Enlarged Detail of Ink Scraping Arrangement.*



(Proceedings Inst. M. E. 1865. Page 166) Scale 1/12th

BANK-NOTE PRINTING MACHINE.

Fig. 8. *Diagram of Cam Motions during one revolution of Cam Shaft.*



(Proceedings Inst. M.E. 1865. Page 166.)

ON THE MANUFACTURE OF COMPRESSED PEAT FUEL.

By Mr. CHARLES HODGSON, of Portarlington.

Improvements on the ordinary mode of preparing Peat Fuel have attracted much attention for many years. All who have considered the subject have felt that the chief difficulty lay in drying the wet peat obtained from the bog; and to accomplish this numerous plans have been tried, for expressing the water from the saturated peat by power, or evaporating it by artificial heat or air currents after having moulded the material into some brick-like form. But none of these methods have been practically successful, because they required that great masses of wet peat should be manipulated before drying; and because air-drying the moulded blocks proved too slow, and artificial drying far too costly an operation.

A system which had in it the elements of success and differed essentially from all previous plans was however proposed by Groynell and others about fifteen years ago. Their idea was to cut peat in the ordinary way and air-dry it to the extent that was possible during the summer in the climate of Ireland; then to grind it and complete its desiccation whilst in a state of powder; and subsequently to compress it in a machine provided with a reciprocating ram, and several moulds capable of being brought successively under the ram. A beautiful sample of hard fuel was thus obtained, but unfortunately the quantity made was limited to samples; for the action of these machines with their moving moulds was complicated, and the strain on the parts was so severe that breakages were of constant occurrence. In addition to these difficulties it was found that the hard and perfect article desired could only be produced when the ram was made actually to stand still at the furthest point of its stroke, and retain the block of peat

under pressure for several seconds. The longer it was thus held without being allowed to expand, the more perfect the block became; but if the pressure was removed at once, as in the case of an eccentric of uniform motion, however slow, the elasticity of the peat was not overcome, and more or less of cracking and abrasion would take place within the next few hours. But in the course of these experiments, tried in 1850 to 1853, the fundamental difficulty of obtaining a large and constant supply of dry peat was never even encountered, because the compressing machinery never stood the test of actual continuous work. Even had these machines been then perfected, it would soon have been found that to grind peat already fit for fuel, and afterwards compress it, would be ruinous in cost; and that to dry artificially peat taken wet from the bog would absorb all the fuel produced and leave none for sale.

The practical difficulties which beset all early attempts in the manufacture of peat fuel have now however been overcome by the system and machinery employed at the Derrylea Peat Works, near Portarlington, where the manufacture of compressed peat fuel has been regularly carried on for some time, upwards of 5000 tons of the compressed peat having been already made there and sold in various parts of the country. The system in use at these works is based on the principle that the drying of the peat is the main difficulty of the manufacture; and this is accomplished by operating continually on thin surfaces of disintegrated peat, instead of on compact sods or blocks; while the compression afterwards employed is used only as a means of rendering the already prepared peat transportable and marketable. The system of drying by thin surfaces is also further carried out by the plan of obtaining the peat from the bog by successive harrowings and scrapings.

In Fig. 1, Plate 35, is given a general plan of the Derrylea Peat Works, showing the mode in which the works have been laid out. The portion of bog at present operated on for the purpose of obtaining the partially dried peat powder or "mull," which forms the raw material for manufacture, is about 1200 yards long by 100 yards wide, covering 24 statute acres. A deep head drain AA cuts off

this area from the remainder of the primitive bog; and it is itself drained by transverse covered shores about 20 yards apart, as indicated by the dotted lines BB, running from this head drain to another main drain CC parallel to it, which forms the opposite boundary of the patch, and runs in fact along the edge of the bog and falls into the natural drainage of the district. The covered shores BB are simply and cheaply formed by cutting drains in the bog about 4 feet deep and 2 feet wide at the top, sloping in the sides so as to leave the bottom 1 foot wide; in this bottom a square groove about 6 inches in width and depth is formed with a tool adapted for the purpose, called a "double-winged slane." Sods cut square from the top of the bog are now placed across the top of this groove; and the peat excavated from the drain is again filled in and levelled on the surface. These drains cost about 2*d.* per yard, and are very effective; they have been used in many parts of Ireland in draining for agricultural purposes.

A railway of the 5 ft. 3 ins. Irish gauge, formed of 36 lbs. T rails well fished at the joints, runs along the centre of this drained piece of bog, being 50 yards distant from each of the main drains AA and CC. It is laid on sleepers of native timber, and carries an 8 ton locomotive without requiring any ballast on the roadway. On these rails runs a six-wheeled truck, 24 feet long, substantially built; and across this truck is laid a square box-lattice girder, 300 feet long, reaching over the entire width of the drained ground, as shown in Figs. 2 to 5, Plate 36. This girder is formed of $1\frac{1}{2}$ inch angle iron at the corners, latticed on each of the four sides with flat bar iron $1\frac{1}{2}$ inch wide by $\frac{1}{4}$ inch thick, leaving 2 feet spaces; it is 6 feet square at the centre, where it rests on the truck, and tapers to 1 foot square at each end, and is stayed perpendicularly and laterally by wire rope stays DD set in taut. This apparatus is propelled by a 6 horse power portable engine, geared down 5 to 1 to the wheels; and it is worked at the rate of about 4 miles per hour, with its great arms stretching over the bog at each side to a distance of 150 feet. To these are attached ten or twelve harrows, each 6 feet square, which by repeatedly passing over the ground scarify it and pulverise the surface to the depth of from 1 to 2 inches. This operation is

performed during any moderately fine weather; and in the mornings and during the day the light powdered surface, which readily dries to a certain extent, is wheeled by men to the side of the railway and wagoned into the works for manufacture.

In dry weather the upper surface of the bog, thoroughly drained as it is, will always contain much less water, perhaps less than half what the general mass retains; and as by this mode of operation a fresh upper surface is being daily exposed, it follows that peat in the most favourable state for drying is being constantly operated on. As soon as the harrowing begins, rapid air-drying takes place, and a very large portion of the water which is not removed by drainage is evaporated by a few hours' exposure. The mull when wagoned into the factory is generally found to consist of about 40 per cent. peat and 60 per cent. water. This may be considered at first sight as but a poor result to attain; an examination however of the state of the bog in its various stages will show that it is not so, the percentage of water and peat contained in the bog being as follows:—

	WATER.	PEAT.
In its primitive state	90	10
When drained as described	84	16
Upper surface of drained portion	75	25
After some hours of an average dry day	60	40

Hence in any method which commenced by working with the primitive bog, 10 tons of material must be dug out and manufactured for every ton of fuel obtained; and if merely well drained bog be used, 6 tons must be carried for every ton produced. But in the system now in operation it will be seen that only $2\frac{1}{2}$ tons of material are required to make the 1 ton of fuel, all the remaining water having been got rid of before the peat left its primitive position.

Thus far the atmosphere may be relied on to perform the difficult duty of drying; and having attained to the state of not more than 60 per cent. water with 40 per cent. peat, it becomes quite possible to employ artificial heat with economy so as to complete the desiccation. At Derrylea the only artificial heat used is that which

is obtained from the waste steam of the compressing engines, and the smoke and gases from the boiler fires, which would otherwise pass direct up the chimney. These are applied in the drying kilns to heat very extensive surfaces formed of sheet iron, on which is spread a thin layer of peat mull, kept in continual and progressive motion by machinery.

The Drying Kilns are shown in Figs. 6, 7, and 8, Plate 37, and consist of four long chambers, each 500 feet long by 16 feet wide inside, containing an upper and lower floor of thin sheet iron plates extending the entire length, as seen in the transverse section, Fig. 7, and to a larger scale in Fig. 10, Plate 38. The walls are of brick, and the kilns are roofed with tiles, which are found well suited to the purpose, giving through their joints sufficient ventilation, and being themselves good non-conductors of heat. The lower floor EE, Figs. 9 and 10, is composed of $\frac{1}{8}$ inch sheet iron plates, rivetted together, which are carried at a height of 18 inches above the ground by a number of clay pipes FF set on end at about 3 feet distance apart. Underneath this floor is blown the smoke and waste heat from the boiler fires; and instead of the ordinary chimney a large fan is used to urge the fires and force the products of combustion under the floor along the entire length of the kilns.

The upper floor GG, Figs. 9 and 10, is 4 feet above the lower one, and is made double for the purpose of being heated by the waste steam from the engines. It is composed in each kiln of five sheet iron steam chambers, each 500 feet long and 3 feet wide, formed of flat plates at top and dished plates below, as shown enlarged in Figs. 11 and 12, Plate 39, the two plates being rivetted together steam-tight along each side with a continuous space between them $2\frac{3}{4}$ inches deep in the centre. These steam chambers are made of sheet iron $\frac{1}{8}$ inch thick, and are carried on cast iron girders H placed 10 feet apart; and they are arranged so as to overlap one another along the sides, as shown in the full-size section, Fig. 13.

An angle iron rail II, Figs. 9 to 12, runs along each side of both the upper and lower floors, at about 3 inches above their level; and along these rails run the wheels JJ, which carry the endless chains K and the iron rakes L for stirring and carrying forwards

the peat mull. The rakes L are placed at intervals of 4 feet, as shown in Fig. 9; and motion is given to them in the direction indicated by the arrows by means of the hexagonal drums MM, round which the endless chains K pass at each end of the drying kilns, whereby the rakes are kept in continuous motion at the rate of about 100 feet per minute. The peat mull as brought from the bog is fed on to one end of the upper floor, and being gradually dragged along by the rakes to the far end of the kiln it there falls down on to the lower floor, along which it is then brought back by the rakes in the same manner. During this drying process in the kilns almost the whole of the 60 per cent. of water which the mull contained is evaporated, and the mull is then in a fit state for being compressed. By an arrangement of bands and elevators, the dried mull is conveyed into a loft over the engine room, Figs. 6 and 7, whence it descends through spouts direct into the mouths of the two peat presses below.

One of the two Peat Presses is shown in Figs. 14 to 17, Plates 40 to 42; Fig. 14 is a longitudinal section, Fig. 15 a plan, and Figs. 16 and 17 are transverse sections of the press.

The strong cast iron frame NN carries the driving shaft O, which is 7 inches diameter, and has forged on it the eccentric P giving a 7 inch throw. This actuates the horizontal ram R of steel, 4 inches diameter; and the ram moves $3\frac{1}{2}$ inches into and $3\frac{1}{2}$ inches out of the breech of the very strong steel tube S, which is 3·ft. 6 ins. long with 4 inch bore. This tube is made of Bessemer steel, bored cylindrical throughout, and turned down outside in a series of cylindrical steps fitting accurately into the cast iron block T, which is secured to the frame N of the press. The spout U brings down the supply of peat mull from the loft above, and the column of dry mull which it contains rests on the moving ram R as it enters and recedes from the breech of the tube S. At each back stroke of the ram, in the position shown in Fig. 14, a portion of the mull falls down and fills the empty space which has been left from the previous forward stroke of the ram, and this material is pushed by the ram into the tube. After a few strokes of the ram, the peat

driven forwards in the tube becomes so wedged in it that a very powerful resistance is offered by the friction against the sides of the tube: so powerful indeed that each successive charge is consolidated into a separate hard block before the whole mass in the tube yields; and it then moves forwards about $1\frac{1}{8}$ inch, that being the length of one block of the compressed peat formed by the compression of about 4 inches length of peat mull at each stroke.

The outer end or nozzle of the tube S is left entirely open, and the compressed peat is delivered from it in a continuous cylindrical bar, which readily breaks up into the separate discs of $1\frac{1}{8}$ inch thickness each, that are formed one at each stroke of the ram. These discs weigh $\frac{1}{2}$ to $\frac{3}{4}$ lb. each, and about forty of them are formed per minute by as many strokes of the ram. As the tube however is 3 ft. 6 ins. long, each block remains about one minute under pressure, which is an essential feature of the process; and the quality of the compressed peat as fuel is further improved by its being made to pass along an open trough continued from the end of the tube to about 300 feet length, from the machine to the peat store or wagon, Figs. 1 and 8, without rupturing the continuous cylindrical bar in which the peat issues from the machine. At the end of this trough the separate discs of the peat having become by that time loosened fall out successively, one being delivered for each stroke of the press.

As this mode of preparing the peat frees it so completely from moisture, it is natural to expect that its duty as fuel will be greatly improved by the process; and it is accordingly found that the peat thus prepared is capable of performing nearly double the work of average common peat, and from 60 to 66 per cent. of the duty of good coal. It is well adapted for the boilers of stationary engines, and for brewers' work; and has found a ready sale for household purposes, its great cleanliness and freedom from smoke being a strong recommendation. The stowage room required is just the same, weight for weight, as that of coal.

A very good gas is made by using one third of cannel coal and two thirds of this compressed peat; but it is probable that from the

application of the peat to the manufacture of iron the most useful results will yet be derived. This fuel has already been applied in the cupola for casting purposes with complete success; and although it requires peculiar treatment, yet there can be no doubt that, possessing as it does many of the good qualities of charcoal, it will become rapidly adopted for most metallurgical processes wherever it can be obtained.

The PRESIDENT remarked that the subject of the paper was one of great importance to Ireland, on account of the vast extent of peat bogs in the country; and he trusted the attempt now being made to utilise the peat in the manner that had been described would prove practically successful. He enquired what was the cost per ton at which the compressed peat could be delivered in Dublin, and whether any quantity could be produced that was required.

Mr. HODGSON replied that the compressed peat was now delivered on the quay side in Dublin at 10*s.* per ton, and at houses for 11*s.* 6*d.* A very large quantity had already been sold in Dublin, but the works were not yet sufficiently extensive to turn out more than a limited make per week, say about 180 tons.

Mr. W. E. NEWTON enquired whether the peat had been tried for the manufacture of iron, and if so how it had been found to stand the blast.

Mr. HODGSON replied that the peat was not capable of standing the blast in a blast furnace, but it had been employed successfully for melting iron in reverberatory furnaces; it was used for that purpose at the Derrylea Works, and was found to stand very well in the reverberatory furnace with a fan blast.

Mr. W. E. NEWTON thought the importance could not be overrated, to Ireland especially, of the manufacture of peat into such a state that it could be made commercially useful. Various attempts at condensing the peat into solid fuel had been made; but

although to those unacquainted with the nature of the substance its preparation might appear an easy task, it was practically one surrounded by a great many difficulties, as was apparent from the description given in the paper that had been read of the process of manufacture carried out at Derrylea. He was glad to learn however that many of these difficulties had now been overcome in the mode of manufacture described in the paper, and hoped that further endeavours would be made to bring the peat into such a state that it might be profitably used in the manufacture of iron. Thus far the peat had only been compressed, which did not appear to be enough to render it applicable to the manufacture of iron; as for that purpose it required to be converted into the state of charcoal, so as to enable it to stand the blast. As regarded the manufacture of gas from the peat, the principal difficulty arose from the fact of the peat containing so large a quantity of oxygen, in consequence of which the amount of carbonic acid gas generated by the distillation of the peat was too great to be easily eliminated from the carburetted hydrogen produced; and therefore the attempts hitherto made to obtain carburetted hydrogen gas from peat had been unsuccessful. It was possible however he believed to drive off a portion of the oxygen by a preliminary process of slightly charring the peat, so as to allow of the subsequent distillation of the carburetted hydrogen without an excessive quantity of oxygen or carbonic acid; taking care however that the heat employed was not too high, otherwise the peat would be converted into charcoal and some of the valuable volatile products lost. The manufacture of gas from peat, when it could be successfully accomplished, would be attended with considerable advantages, because the peat contained a number of other useful products, such as peat charcoal and peat grease, which was a good lubricator; and these would not only pay for the manufacture of the gas but would yield a sufficient profit in addition.

He had himself paid some attention a few years ago to the question of the manufacture of peat, and found that a very general interest was felt in the subject by landowners throughout the kingdom, particularly in Ireland and Scotland. Many attempts

had already been made to compress peat, and to expel the water from it by pressure; but it appeared to be a peculiarity of this substance that, notwithstanding any amount of pressure that was used, it was not possible to express the water from the peat beyond a certain percentage, which was loose, as it were, amongst the fibres. The only truly efficient plan of getting rid of the water seemed to be that carried out at the works described in the paper, by exposing a very extensive surface of the peat to the atmosphere so as to allow the water to be evaporated. He had seen a plan somewhat similar in principle, though differing in detail, successfully carried out by Mr. Buckland at Creevelea, about 14 miles from Sligo. The bog was first drained as much as possible by trenches cut through it, and then the black watery and greasy peat was taken from the bottom of the bog, and in that state was put into a conical vessel perforated with a number of holes, having a central shaft with a broad-bladed screw and radial arms upon it. This formed a sort of pug mill, and as the shaft turned round, the peat was forced out through the small holes in the form of long strings like vermicelli, and in this finely divided state a very large quantity of the water became readily and quickly evaporated by the air. After a further drying by passing through a drying chamber the peat was finally consolidated in a press; but it had not been found necessary to employ any considerable amount of pressure for the purpose: a handful of the material could in fact be squeezed by hand into a sufficiently solid form for all practical purposes to which it was intended to be applied. The peat might therefore be said to be simply moulded into shape rather than compressed; and when the moulded blocks had been further dried in a drying chamber and properly charred, it was found they would bear almost any amount of blast to which they might be subjected in a blast furnace. This process of peat manufacture was already being carried out at Mr. Danchell's ironworks at Horwich in Lancashire, and also at Creevelea, to a sufficient extent to prove its utility; and he exhibited a piece of pig iron produced at Creevelea, which he considered a very good sample of iron. It was made from iron ore found in that neighbourhood, and smelted in the blast furnace

with peat manufactured according to this process, and was called Irish charcoal iron. The cost of production was estimated at about £1 13*s.* 6*d.* per ton of pig at the works, exclusive of wear and tear and interest upon capital; and the cost of bar iron made with peat charcoal from the same pig iron was estimated at about £4 11*s.* per ton at the works, or £4 16*s.* per ton delivered on board at Sligo, 14 miles distance. The cost of the peat charcoal at the works was about 6*s.* per ton, and the quantity required in the blast furnace was about 30 cwts. per ton of pig iron made, and in the puddling furnaces about 35 cwts. per ton of bar iron produced. The steam for the blast engine and forge engine was raised by the combustion of the waste peat left in the process of manufacture.

Mr. Hodgson observed that the process just described for peat manufacture confirmed his own experience as to the chief difficulty to be contended with, which was to get rid of the water contained in the peat; but he thought the plan proposed for the purpose was open to much objection. For by taking the peat wet from the bottom of the bog, 8 or 9 tons of water had to be handled for every ton of peat afterwards made; and the solidification of the peat into blocks, after its fine subdivision by the ingenious process that had been mentioned, depended upon the evaporation of this large quantity of water by artificial means. Artificial drying however could only be produced either by the direct application of heat, as at Derrylea, or by an air blast, which must be generated by steam power and would therefore involve consumption of fuel. Supposing the wet peat from the bog to contain only 8 tons of water per ton of peat, then there must be at least 7 tons of water dried out of it before it could be consolidated; and in order to derive any profit from the manufacture, it would be necessary that 1 ton of peat should not merely be capable of being economically applied to dry out 7 tons of water, but that it should also leave a sufficient surplus of fuel for sale, which was evidently altogether impracticable. For it was not bad duty for a Cornish boiler to evaporate 7 tons of water with 1 ton of coal of the ordinary kind; and peat was not so good a fuel as coal, and the mode of its application to drying purposes could not be so advantageous as when used under a boiler.

In the manufacture of peat at Derrylea the bog was first drained as much as possible, which would of course be done in any case, whatever process of manufacture were adopted. But instead of taking the wet peat from the bottom of the bog, a thin portion of the surface only was operated upon, which was always the driest; and by repeatedly harrowing this over, the peat was so far dried by the exposure to the air that it was obtained from the bog with only $1\frac{1}{2}$ ton of water per ton of peat, making only $2\frac{1}{2}$ tons total weight to be handled, the rest of the water having been evaporated out by the atmosphere, before any artificial drying was attempted. Until this advantage was gained of obtaining the peat dried to that extent by natural means, he did not think there was any use in attempting to dry the peat artificially; but when the peat was already brought by natural drying to such a state that it contained only $1\frac{1}{2}$ ton of water per ton of peat, then it was practicable, with 1 ton of peat to expend, both to get rid of this remaining $1\frac{1}{2}$ ton of water and to have still a large proportion of the peat left for carrying on the manufacture and for sale. This was what had been found to be the case in the actual working of the system at Derrylea, and the plan there carried out was the only one at present he believed that had stood the test of actual commercial manufacture, the other process that had been referred to not having yet been carried so far as the actual manufacture of the peat for sale.

The PRESIDENT remarked that in reference to the use of peat for the manufacture of iron he remembered a small quantity of iron being manufactured with peat only at the Muirkirk Iron Works in Ayrshire about twenty-five years ago: it was made for the axles of carriages, and proved far better than any other iron manufactured at that time either in England or Sweden.

Mr. I. SMITH enquired whether the peat had been tried for the manufacture of lighting gas, and what was found to be the illuminating power of gas made from peat alone. He understood that in some parts of Germany, where the only fuel to be had was wood, it had been endeavoured to obtain from wood a lighting gas; but this being nearly all hydrogen was of a very poor illuminating quality. A plan had however been devised by Liebig for increasing

its illuminating power by passing it a second time through the retorts; for it appeared that the heat which was sufficient to distil the lighting gas in the first instance from the wood was not enough to decompose the carbonaceous parts of the wood; but by first distilling off the gas at this moderate temperature, and afterwards increasing the heat to such an extent as to get the carbonaceous portion of the wood decomposed, the gas on being then passed a second time through the retorts took up sufficient carbon to give it a high illuminating power. By this means a very beautiful lighting gas was produced, almost equal to that obtained from cannel coal, and without any of the ill effects of sulphur; and several towns in Germany were now lighted with gas produced in this manner from wood. As peat had the same advantage of freedom from sulphur, he thought it would be a great benefit if it could be made to yield such a gas for illuminating purposes.

Mr. Hodgson replied that they had put up a small gas apparatus at Derrylea, which was employed successfully for lighting the works. A mixture was used of two thirds peat and one third cannel coal, and the gas produced from this mixture compared advantageously in illuminating power with the ordinary coal gas made in Dublin, while the quantity made exceeded he believed that obtained from coal alone. He had heard of the process that had been mentioned for increasing the illuminating power of gas obtained from wood, and hoped to try it shortly with the peat; hitherto the main object had been to turn out a sufficient quantity of manufactured peat for commercial purposes, and having now succeeded in doing this, he hoped further to perfect the various uses to which the peat could be applied.

The President enquired whether the sheet iron floors of the drying chambers had been found to become corroded by the constant passage of the peat over them.

Mr. Hodgson replied that the drying chambers had been in use continuously ever since their erection fifteen months ago, and the floors did not show any signs of wear or corrosion. He had not seen the inside of them since they were put up, but the outside was

as smooth and clean as possible, and there were no signs of any corrosion having occurred; the thickness of the plates was only 1-8th inch.

Mr. W. E. Newton enquired how long the peat was in passing through the drying chamber.

Mr. Hodgson believed the time occupied by each portion of the peat in passing through the drying chamber to the extremity and back again was about from 1 to $1\frac{1}{2}$ hour.

Mr. H. W. Harman enquired whether the form in which the peat was now exhibited of circular discs was the form in which it was supplied for commercial purposes; and what space the compressed peat occupied per ton.

Mr. Hodgson replied that the peat was supplied in the form of discs, like the specimen exhibited, 4 inches diameter and rather more than 1 inch thick, and 1 ton of the peat in that form occupied about 44 cubic feet in ordinary stowage without packing. It was delivered in Dublin in the ordinary coal sacks used for delivering coal; the sacks were filled rather fuller with the peat than with coal, and were reckoned at sixteen sacks per ton.

Mr. J. Fernie suggested that it would be preferable if the form of the peat discs were made hexagonal or square, so as to allow of packing them without loss of space between.

Mr. Hodgson said that if the peat discs were made hexagonal or square it would be necessary to pack them by hand in order to obtain the benefit of saving the space between; and it would then be found practically that the expense of packing would counterbalance the advantage of the space saved.

Mr. J. Kennan enquired whether any attempt had been made to harrow the surface of the bog by employing wire ropes to draw the harrows in a similar manner to the plans adopted for working agricultural implements, instead of using the long girder frame travelling over the bog and having the harrows attached to it, as described in the paper; or whether the use of wire ropes was considered to be attended with any practical disadvantage for the present purpose. He asked also whether the final form of discs, in which the peat was supplied, was produced by the

compression alone, or whether there was any further drying process subsequent to the compression, and what percentage of water remained in the peat after its manufacture into the discs supplied for sale; and also what had been found to be the durability of the steel cylinder in which the peat was compressed.

Mr. Hodgson replied that he had consulted the late Mr. Fowler respecting the application of ropes for working the harrows over the bog, but that plan had never been tried for the purpose, as it was found it would be so expensive; and the present mode of working with the long girder was so much more simple and appeared so much better adapted to the circumstances of the case that it was adopted instead, and had proved perfectly successful. With regard to the drying of the peat, there was not any subsequent drying after compression, and the dried mull from the drying chamber that was supplied to the peat press was as dry as it was required for commercial purposes. He did not know with certainty what average quantity of water then remained in the peat, but it was not more than 6 or 7 per cent. and frequently much less.

In reference to the durability of the steel tube in which the peat was compressed, the first portion of the tube where the disc of peat was formed by the pressure of the ram became worn away 1-8th inch all round in three weeks' working. It was then taken out and a spare tube substituted, while the first tube was bored out at the mouth and a steel bush put in; the cost of doing this amounted to about 15*s.* or 16*s.*, and it required to be done every three weeks. The entire tube required to be bored out and bushed throughout its whole length about once every four months. The same outside tubes were still at work that had been employed at starting two years ago, although they had been repeatedly bushed in working. The outer end of the tube was prolonged and turned down to 3-8ths inch thickness, as shown in the drawing (Figs. 18 and 19, Plate 42), and then split up with four saw cuts; and a tightening clamp was placed upon it with screws for tightening it up, so that the tube could be slightly contracted towards that end. The peat when it got past the solid part

of the tube had a tendency to expand slightly, and this expansion was counteracted and a slightly increased pressure put upon the peat by tightening the clamp upon the tube; by this means also the resistance offered to the ram of the press was regulated to a certain extent. Without the power of increasing or diminishing the friction in the tube in this manner, as might be required, it might occasionally happen from variations in the state of the peat that there was too much or too little pressure upon the peat in the formation of the discs. If the mull were of rather a light quality, and the clamp were not on, it sometimes happened that the column of peat would slip in the tube, so that the pressure against the ram ceased; but by then tightening up the clamp the resistance was increased until the pressure was brought up again to the point necessary for the proper formation of the discs.

The President enquired whether the ram of the press was found to wear as rapidly as the tube, and how it was repaired when worn.

Mr. Hodgson replied that the end of the ram became worn a little all round the edge in about the same time that the mouth of the tube required to be rebushed; and the face of the ram was then "jumped up" by heating it and hammering it up to the full size of face, after which it was turned and faced again in the lathe.

Mr. F. W. Webb suggested that the bushes of the tube and the face of the ram might be casehardened, in order to render them more durable.

Mr. Hodgson said the bushes in the tube were all casehardened, but he had not yet tried casehardening the ram also.

Mr. J. Ramsbottom enquired whether chilled cast iron had been tried for the bushes of the tube; he thought that would be a better and more durable material for the purpose than steel.

Mr. Hodgson said he had not tried chilled cast iron for the bushes, but he had thought of making the whole length of the tube of chilled cast iron, by casting it upon a hollow mandril filled with cold water.

Mr. J. Ramsbottom observed that there would be some objection to making the long tube itself of chilled cast iron, as it would then

have to be ground out afterwards, which would be a troublesome operation in a tube of that length; unless indeed it were not chilled so hard as to prevent its being bored out in the usual manner.

With regard to the mode of finally drying the peat mull in the drying chambers, he thought there must be a considerable amount of oxidation on the steam side of the plates composing the hollow floors, and being only 1-8th inch thick they could scarcely be expected to prove very durable; and he enquired whether the use of hot air had been tried for drying the peat, to avoid having to make use of steam for the purpose. He suggested also that by the use of hot air the arrangement of travelling scrapers for carrying the peat along the floor of the chamber might be dispensed with, by carrying the peat upon an endless belt travelling in the opposite direction to the current of heated air.

Mr. Hodgson replied that he had tried drying the peat by blowing a current of hot air through it, but there were practical difficulties in the way of carrying out that plan, and the air blew away a great deal of the finer portion of the peat powder, causing a serious waste; and that mode of drying had not been found to answer so well as the exposure of the peat in a thin layer with a large extent of surface, as was now done in the drying chambers with the hollow floors heated by steam. He did not think it would be advisable to dispense with the scrapers now employed for scraping the peat along the floors of the drying chambers, because then the peat would not be stirred at all; and if carried upon an endless band it would go forwards in the exact position in which it fell upon the band, and would not receive that continuous stirring which was so essential a feature of the present arrangement, exposing constantly a fresh surface to be dried by the heat.

The President enquired what extent of bog was now being worked over with the harrows under the system described in the paper, and whether the working had been confined to one part of the bog or had been carried on in different places. He asked also whether the bog was found to sink much after being drained.

Mr. Hodgson said the working had been confined hitherto to one portion of the bog, of about twelve acres, which was not yet

half exhausted after two years working. After draining the bog in the first instance it sank fully one third of its depth.

Mr. J. Whitley enquired whether any use had been made of the ashes after burning the peat; he thought they would be found very beneficial in smelting iron, by mixing them with the fuel in the blast furnace.

Mr. Hodgson replied that he had kept the ashes made at the works from the peat burnt in the furnaces, thinking they might perhaps be sold at a low price for agricultural purposes; but he had not supposed that any application could be made of them in connection with smelting iron.

The President proposed a vote of thanks to Mr. Hodgson for his paper, which was passed.

The Meeting was then adjourned to the following day. In the afternoon the Members were conveyed by free train, by the kindness of the Dublin and Wicklow Railway Company, to Carrickmines, to visit the Lead Smelting Works of the Mining Company of Ireland at Ballycorus, where they were shown the various operations connected with the smelting of the lead ore and the separation of the silver, the manufacture of sheet lead, lead pipes, and red lead, the refining of the silver extracted from the lead, and the manufacture of shot at the shot tower. The Members were hospitably entertained at the works by the directors and officers of the Mining Company; and afterwards returned to Dublin by free train.

In the evening the Members were invited by the Local Committee to a Conversazione at the International Exhibition, which was specially lighted up for the occasion. In the machinery department, the portable steam rivetter described at the meeting was shown in operation, rivetting plates of $\frac{1}{2}$ inch thickness with $\frac{7}{8}$ inch rivets.

The Adjourned Meeting of the Members was held in the Examination Hall, Trinity College, Dublin, on Wednesday, 2nd August, 1865; Robert Napier, Esq., President, in the Chair.

The following paper, by Mr. Thomas Grubb, of Dublin, Engineer to the Bank of Ireland, communicated through the President, was read:—

DESCRIPTION OF THE BANK-NOTE PRINTING MACHINE AT THE BANK OF IRELAND.

By Mr. THOMAS GRUBB, of Dublin.

In the manufacture of Bank Notes, the printing has usually been accomplished from engraved plates, as affording a better protection against fraudulent imitation; but the slowness and consequent increased expense of this manner of printing, as compared with ordinary type or surface work, have led in some instances to the abandonment of the finer and better protective process. Improvements of a minor character have been made from time to time in the presses used for printing from engraved plates; and the note-printing press of the late Mr. John Oldham, long in use in the Bank of Ireland and subsequently in the Bank of England, may be mentioned as perhaps the best example. But any attempts to abridge the labour and time of the operation by inking the engraved plates by means of machinery appear to have failed entirely, previous to the construction by the writer of the machine to be described in the present paper.

The process of printing from an engraved plate may be considered as divided into three separate portions, namely: first, the inking of the plate; second, the wiping of the plate; and third, the taking of the impression, including laying and removing the paper. All these are usually performed by hand, excepting the actual taking of the impression by the press; and each of the three operations occupies about the same time in performance, in consequence of which all three operations are arranged to be proceeded with simultaneously in the machine about to be described.

The Bank-Note Printing Machine is shown in Figs. 1 and 2, Plates 43 and 44; Fig. 1 is a side elevation, and Fig. 2 a vertical section taken at right angles to Fig. 1.

The machine consists of a horizontal polygonal cylinder A, Figs. 1 and 2, of twenty sides, on ten of which are held the ten engraved plates from which the notes are to be printed. These ten engraved plates are held in position in dovetails formed by ten plain plates screwed upon the ten intermediate sides of the polygon. The plates and polygon are maintained at the proper temperature for working by steam admitted inside the hollow polygon through the back bearing B, Fig. 2.

At the ordinary rate of working, each impression occupies 10 seconds; and the polygon is held stationary during 8 seconds of the time, and during the remaining 2 seconds it is turned round through 1-10th of a revolution, in the direction shown by the arrow in Fig. 1, so as to bring the next engraved plate to the top for being printed from. During the 8 seconds that the polygon is stationary, the undermost plate at C is inked by the machine, the uppermost plate at D is printed from, and the plate at E has the wiping of its surface completed. The machine requires two attendants, one standing in the box F, who lays the paper, removes it after being printed, and observes that the work is proceeding satisfactorily; while the other gives the final wiping by hand to the surface of each plate as it comes into the position E, Fig. 1. The greater portion of the superfluous ink is wiped off by the machine, thereby lessening the labour of the final wiping by hand; this is done by means of the wiping roller G, on which is wound a length of cotton cloth. This wiping roller is stationary while the polygon is at rest; but on the polygon beginning to move, the roller presses against the surface of the previously inked plate, and by turning in the opposite direction wipes off the superfluous ink. When the surface of this roller becomes surcharged with ink, a length of the cotton cloth upon it equal to one round is torn off. By the revolution of the polygon therefore each plate on arriving at the bottom at C is inked, and as it proceeds upwards is first partially wiped by the machine at G, and afterwards finally wiped by hand

at E, and on arriving at the top is printed from by the printing roller D.

Several special contrivances are required for producing the respective actions of the machine, the principal of which are the apparatus for locking and turning the polygon, and for the motions of the printing roller, and the inking apparatus.

At each printing the polygon is subjected to a heavy strain by the vertical pressure of the printing roller D, Fig. 1, tending to turn it first in one direction and then in the opposite direction alternately, as the printing roller passes over from one side of the centre to the other; it therefore requires to be very firmly locked during the time that it has to be held stationary for printing. This is effected by the locking lever H, which being lowered by its cam inserts the steel tooth I into one of the ten spaces round the circumference of the polygon. The turning of the polygon through one tenth of a revolution between each printing is accomplished by the levers and cams K K and L L; one of these levers K alternately withdraws and protrudes the tooth J, while the other L moves the carrier box M through the required arc. The action of the levers H and K is so arranged that as the tooth of the locking lever is withdrawn that of the turning lever enters the toothed circular plate N and *vice versâ*. The polygon is thus sure to be duly acted upon, and always under restraint, thereby ensuring against risk of accident, which might occur if ordinary means were employed for turning the polygon.

For working the printing roller D, Figs. 1 and 2, the ordinary method of causing it to roll up an inclined plane into contact with the plate was inadmissible in the present machine, and the following arrangement has been adopted for the purpose instead. The roller is first caused to descend vertically at the proper time and with a sufficient pressure upon the plate, on which the paper to be printed is previously laid: next the roller is carried horizontally over the surface of the plate, to produce the impression; and thirdly it is raised from the plate and withdrawn to its first position. The motion of the centre of the roller is therefore as shown by the dotted

line P Q R in Fig. 3, Plate 45; and this motion is produced in the following manner. The vertical descending movement from P to Q is effected by the long trussed rod O and its double cam, acting on the bell-crank S and toggle-lever joint T. The horizontal traverse from Q to R is produced by the printing cams and their levers U acting upon the sectors V, Figs. 2 and 3. These sectors roll against inverted straight edges W, and the bearings of the printing roller D being concentric with the arcs of the sectors V, the roller is traversed horizontally over the engraved plate. The curved motion from R to P, in withdrawing the printing roller and returning it to its original position, is produced by the joint action of the two sets of cams. The blocks W, against which the sectors V roll, slide vertically in grooves in the side frames of the machine; the underside of these blocks is faced with a flat surface of hardened steel, against which rolls the upper segmental surface of the sectors, which is also made of hardened steel. These steel bearing surfaces are retained in contact by the spiral springs X, Fig. 2, which carry the weight of the sectors, the printing roller, and the levers U. The sectors are prevented from slipping in rolling against the blocks W, by means of bridle levers, which admit of motion in other directions, but prevent slipping. An endless sheet of flannel Y passes round the printing roller D and over the guide rollers Z above, travelling in the direction shown by the arrows in Fig. 3; the upper rollers Z are carried by the sectors V and slide blocks W.

The inking of the engraved plates is performed by the inking roller C, Figs. 1 and 2. Upon the capability of the machine to ink the engraved plates effectively depends its usefulness; and herein lay the main difficulty, and the reason of the failure of previous attempts at improvement. The difficulty was much enhanced by the circumstance that, in using the ink applicable to engraved plates, a portion of it becomes thickened and unfit for immediate use. In the ordinary hand-inking this thickened ink collects in a ring on that part of the dabber which barely comes into contact with the plate during the inking; and this requires to

be removed occasionally from the dabber by a knife or scraper, otherwise by its mixing with the fresher ink the quality of the work would be injured. In experiments made preliminary to constructing the present machine, a cylindrical roller was used for inking the plates by hand, and was supplied with ink from a perforated surface, through which the ink was caused to exude; and it was found that the thickened ink, technically termed "gatherings," adhered at first to the perforated surface between the perforations, and afterwards when the film had arrived at a certain thickness it was transferred bodily to the surface of the inking roller. These experiments led to the adoption of the following inking apparatus.

The short cylinder P, Figs. 1 and 2, containing the supply of ink, is fitted with a piston, the rod of which is a screw that projects below the cylinder, as shown in Fig. 2. The upper end of the cylinder expands into a horizontal rectangular tray, rather larger in size than the plate to be inked; and this tray is covered with a flat plate of steel, perforated with a number of small holes. The piston is slowly raised by the screwed piston-rod and the bevil wheels Q and ratchet wheel R. In order to charge the cylinder with ink the piston is lowered and the perforated top plate removed for filling in the ink; and on replacing the top the piston is raised until the ink exudes through the perforations in the top plate, the lowering and raising of the piston being effected by hand by a winch upon the spindle of the ratchet wheel R. The supply of ink during the working of the machine is kept up by the lever T from the cam shaft, Fig. 1, acting on the ratchet wheel R, a small but sufficient quantity of ink being in this way forced up through the perforated surface for every plate inked by the inking roller C.

The inking roller C, shown enlarged in Figs. 4 to 6, Plate 46, is formed of a number of discs of woollen cloth, screwed up tightly together upon a spindle and finished in the lathe. It is worked to and fro continually without intermission by the rack and sector B. This rack slides on a cylindrical rod D, which allows the frame E carrying the roller to be raised and lowered sufficiently for causing the inking roller either to apply ink to the engraved plate on the polygon A above, as shown in Figs. 4 and 5, or to descend and roll

on the inking table P below, for obtaining a fresh supply of ink, as shown in Fig. 6. The roller is held up for inking the polygon by the weighted lever G, having an adjustable weight; and on the pressure of this weight being removed at the proper moment by a cam, the roller C drops and rolls upon the inking table P with its own weight and that of the frame E, as shown in Fig. 6. It thus takes up a fresh supply of ink, while the polygon is turned through one tenth of a revolution so as to bring the next engraved plate round into position, ready to be inked when the inking roller is raised again by the lever G.

As the ink is transferred from the perforated inking table P to the inking roller C in a series of dots through the holes in the inking table, the engraved plates would be inked in a similar and therefore imperfect manner; but this is prevented by the application of the two small distributing rollers I I, which are pressed in contact with the inking roller by springs. One of these distributing rollers simply revolves in contact with the inking roller; but the other has one of its bearings a screw, which gives it an end traversing motion in addition to the rotary motion; and thus the ink coming to the roller in dots is equalised over its entire surface, and the inking of the engraved plates is rendered uniform all over.

The occasional removal of the thickened ink from the surface of the inking table P is provided for by the arrangement shown in Fig. 7, Plate 47. The ink scraper J is shown in the position when out of action, and H is the lever and M the connecting rod for communicating the required motion to it from the cam N. On the scraper beginning to move across the inking table P from the position shown at J in the drawing, a small cam at each end causes it to rise and so to pass clear over the table without scraping; while in the return motion the scraper descends into contact with the table, and pushes before it the thickened ink, which falls into a trough placed to receive it.

If the scraping were to be performed once for every impression printed, then it would only be required to allow the cam roller at the end of the lever H to remain continually in the groove of the

A 2

cam N. But as it is required that the scraping should be performed only occasionally, or once for every 36 impressions or revolutions of the cam shaft, the following arrangement is adopted. At O is a latch, which so long as it is not raised holds the connecting rod M pushed outwards laterally, so that the cam roller is out of the cam groove N. The ratchet wheel Q has 72 teeth, and is carried forwards one tooth for every impression by the paul R, which is actuated by the cam shown by the dotted line. Attached to the ratchet wheel is a disc S, having only two notches T T in its circumference; and U is a rocking frame, rocking on a pin at its lower end, and having on the upper part a projecting finger, which is caused by the weight W to press continually against the edge of the disc S. V is a bolt, worked up and down at each revolution of the cam shaft by the same lever and cam that work the paul R of the ratchet wheel. The upper end of this bolt slides in the rocking frame U; and so long as the finger is on the edge of the disc S, the bolt V rises and falls just clear of the latch O, as shown in the drawing, so that it produces no action.

But once for every 36 impressions of the machine the finger of the rocking frame U enters one of the notches T in the disc, and the rocking frame falling forwards tilts the bolt V into the position indicated by the dotted line, when the next rising of the bolt lifts the latch O, as shown by the dotted line. The cam roller is now thrown into the cam groove N by the lateral pressure of the spring lever H, and the scraping of the inking table P is performed once by the revolution of the cam N. At the end of the revolution the cam roller is thrown out of the cam groove N by the inclined stop X at the end of the groove, and is instantly held out by the dropping of the latch O; and before the bolt V again rises, the ratchet wheel Q has been turned forwards one tooth, so that the finger of the rocking frame U is again out of the notch T, and therefore the bolt V rises clear of the latch O and ceases to lift it for the next 36 impressions.

In the planning and also in the construction of the present machine and other similar ones, the writer has derived much advantage from

the use of Babbage's system of mechanical notation by means of a chart. In the construction of automatic machines, where there are of necessity interrupted or occasional movements, there is frequently much improvement to be effected upon the original foundation; and this is usually accomplished by expensive mechanical alterations. But the use of a chart admits of its being done much more readily and efficiently, and this system also provides by inspection the data for the required curves of the several cams, and for keying the cams at once upon their shafts in the exact positions required, without recourse to tentative trials.

In Fig. 8, Plate 48, is shown the diagram of the principal cam motions in the bank-note printing machine, as used in the construction of the machine, showing the respective motions during one revolution of the cam shaft.

The President thought the machine described in the paper was very beautifully contrived for the purpose; he had had an opportunity of seeing it at work, and had been much struck with the simplicity of its construction, and the accuracy of its working. He enquired what was found to be the durability of the wearing parts, and whether any of them had required to be replaced.

Mr. Grubb replied that there were two of the machines described in the paper in use at the Bank of Ireland for printing the bank notes, one of which had been in constant use for about fourteen years with scarcely any repairs, and was still working quite as well as when first started. The only renewal had been in the case of the pressing cam upon the main driving shaft, which gave the heavy pressure upon the printing roller for working off the impression; this cam had required to be renewed once, after being in constant work for about fourteen years. The only other defect had been in the

original casting of the polygons for both the machines, in consequence of the unequal contraction of the metal in cooling, which caused one end to give way in each polygon by separating from the circumference of the polygon, showing that the metal had been subjected to a considerable strain in the cooling of the casting. This difficulty was obviated in each case by cutting out the end of the polygon and bolting on a new end, to avoid having to re-cast the polygons; this had proved completely satisfactory, and the polygons had worked ever since with entire success.

The President enquired what was the amount of pressure upon the printing roller when in operation.

Mr. Grubb said the total pressure upon the printing roller was about 3 tons, which obliged considerable force to be exerted by its cam. A very heavy pressure was required, in order to make sure of producing a good impression in all parts of the note that was being printed.

The President enquired whether the engraved plates were found to wear out faster when printed by the machine than in ordinary hand printing.

Mr. Grubb had not found any difference in the wear of the plates in printing by the machine. The principal source of wear was the use of the whiting employed for the final cleansing and polishing of the engraved plates by hand immediately before the impression was taken; for though the whiting was employed in the state of a soft fine powder, it had a slight cutting action which gradually wore away the engraved plates; and this polishing process was the same in either case, whether the printing were done by hand or by the machine.

The President enquired how the plates were engraved in the first instance, and what means there was of renewing the engraving when it became faint in any places in consequence of the wear.

Mr. Grubb explained that the separate subjects or designs forming the complete bank note were engraved by hand in the first instance on separate steel blocks, which were afterwards hardened and were preserved as the permanent patterns, not to be printed from. The engravings were then transferred in relief to the surfaces

of soft steel rollers, by rolling these over the pattern blocks under a heavy pressure; and the rollers being afterwards hardened were used as dies to impress the engraving upon the printing plates, in a similar manner to that long employed for engraving the copper cylinders used in calico printing, but requiring a far greater amount of accuracy in the present instance. The engraved plates for printing the bank notes were made of soft steel, and were never hardened after being engraved, because being of large size, 20 inches long by 6 inches wide, they would almost certainly not retain their flatness in hardening. Moreover when worn in printing the soft plates were easily repaired again by means of a special arrangement that he had designed for the purpose, which enabled the rollers to be applied again to the plates with perfect accuracy for renewing the impression. In first impressing the plate with the master roller or die, the plate was fixed upon the table of a strong pressing machine, capable of exerting a pressure up to 5 tons, regulated as required by means of a weighted lever; and the position of two register points in the plate being accurately noted by means of a micrometer microscope was registered in a book kept for the purpose; the master roller was then passed over the plate by the machine under the heavy pressure, being very steadily guided by a special parallel-motion arrangement, with pressing sectors similar in principle to those of the note-printing machine described in the paper. The table was provided with complete adjustments of very great delicacy, and the pressure of the engraving roller upon the plate was not produced by the roller descending upon the plate, but by the table being raised up to the roller: the table being of considerable weight was balanced, so that it was moved vertically with a force of a few pounds; and it was provided with two separate lever arrangements, one for light and the other for heavy pressures, whereby any pressure from a few pounds up to the 5 tons could be put upon the plate. For renewing the impression on any subsequent occasion, the plate was again fixed upon the table in exactly the same position as before, by means of the micrometer microscope and the register of its position; and the roller was then passed over it again, to deepen those parts of the impression

which had become worn in printing. The accuracy with which the renewal was effected by this means was so perfect that the finest lines in the engraving were preserved without becoming perceptibly coarser even after the plate had undergone renewal many times; and the most delicate engravings on the plates when worn by the process of printing were restored as often as required with the greatest certainty and facility. By a delicate adjustment in the bed of the table, the plate could be slightly tilted, transversely to the direction of motion of the roller, so as to give the means of bringing up the impression on any special portion of the plate by increasing the pressure upon that part. This tilting motion was effected by the bed being made with a convex cylindrical segment lying within a concave one, the plate to be engraved being in the centre of motion; and the movements for adjustment were effected by screws, which gave facility for adjustment to the thousandth of an inch.

Mr. R. Mallet remarked that scarcely sufficient prominence had been given in the paper just read to the very important improvements that had been effected by the writer himself in the invention of the beautiful bank-note printing machinery now employed in the Bank of Ireland, which could not be fully appreciated without a reference to the imperfect method previously in use for printing bank notes.

Prior to about the year 1820 all bank-note printing was performed by hand labour alone, by copperplate printers, in the same way as the printing of fine art engravings. About that time the elder Mr. John Oldham, who had been a working calico printer, devised machinery for performing the printing of bank notes by mechanical means, which was constructed by Mr. John Mallet of Dublin, and employed for several years at the banks both of Ireland and of England. Steel engraving being then unknown, the impressions were taken from copper plates, inked and cleaned by hand in the old way, and heated on flat steam tables on which they lay during the process. The plate was then laid upon the table of the printing press, which consisted of a pair of horizontal rollers, one above the other, between which the table carrying the plate was

passed under a heavy pressure. The table was made of gunmetal in two pieces, each of a flat wedge shape, sliding upon each other with much accuracy ; so that the top and bottom surfaces of the table always remained parallel to each other, whilst the total thickness was increased or diminished as desired by sliding the wedges over each other. When the copper plate was laid upon the table, the under wedge was slided home, bringing the plate into contact with the top roller ; and it was then passed through under severe pressure, taking off an impression upon the sheet of paper placed upon the plate. The idea was thus to print " skin to skin" as it was called, relying upon the accuracy of all parts of the machine being sufficient to produce a good impression without the intervention of any elastic medium, the only elasticity being that of the thin sheet of bank note paper itself. This was ultimately found to be impracticable, and some elastic material such as felt was afterwards used in either one or both of the pressing rollers. To the end of Mr. Oldham's career however, and that of his son, very much of the work of printing the notes was performed by hand ; in fact the use of machinery was confined to rolling off the impressions from the plates, which were inked and wiped by hand, and transferred by hand to the printing machine. Even the numbering machines he believed were worked entirely by hand, and required changing by hand after a certain number of figures had been passed.

Upon Mr. Grubb's appointment as engineer to the Bank of Ireland in 1842 he departed at once from all existing plans for bank-note printing, and produced the automatic machine described in the paper ; and nothing could be more striking than the perfection of its action, and the foresight with which every part of the process of printing the notes had been provided for. The machine presented one of the most beautiful combinations of cam work that was to be met with, enabling it to perform with strict accuracy very complex and peculiar movements, involving both very severe pressure and extreme delicacy. The numbering machines also had been greatly improved by Mr. Grubb, increased in their numerical range, made self-inking, and rendered completely automatic.

The President moved a vote of thanks to Mr. Grubb for his paper, which was passed.

The following paper was then read:—

ROCK BORING MACHINE.

Fig. 1. *Sectional Plan, showing Boring Tool commencing the Hole.*

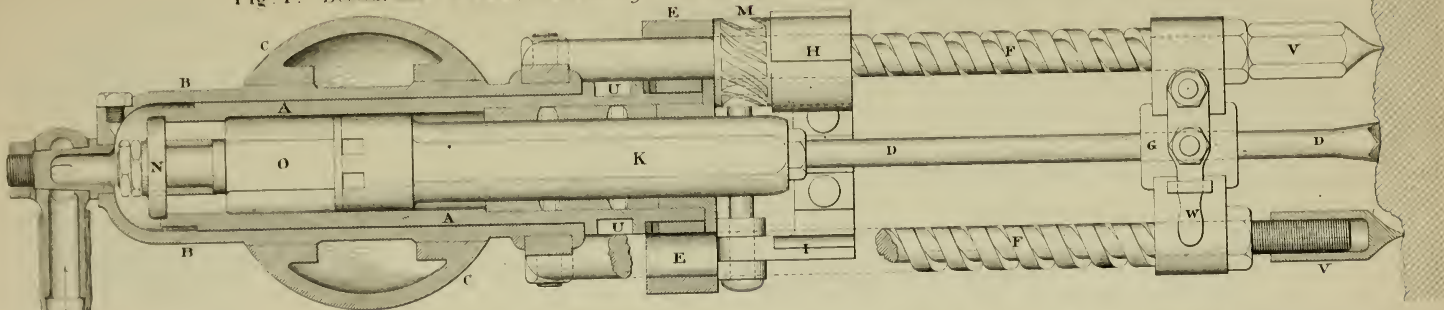
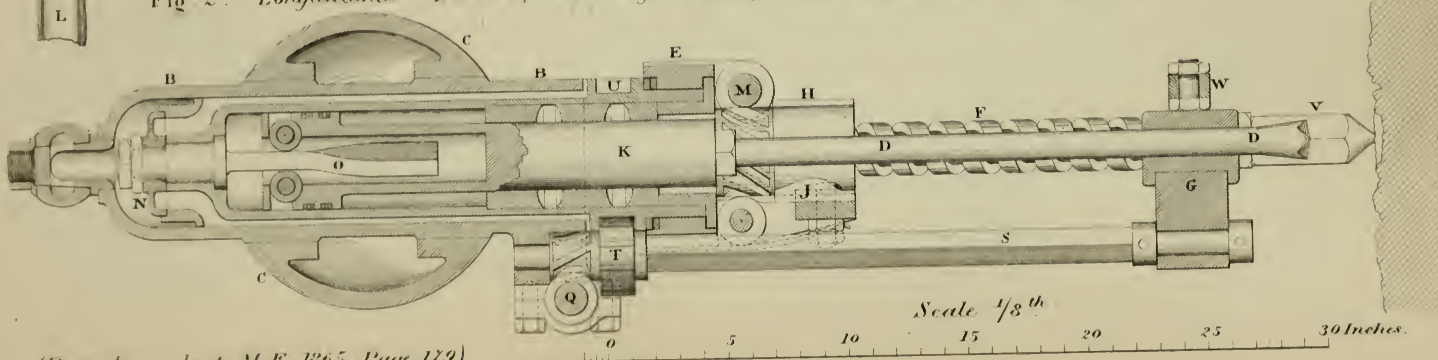


Fig. 2. *Longitudinal Section, showing Boring Tool at end of Return Stroke.*



ROCK BORING MACHINE.

Fig 3. *Sectional Plan, showing Working Cylinder advanced as the Hole progresses.*

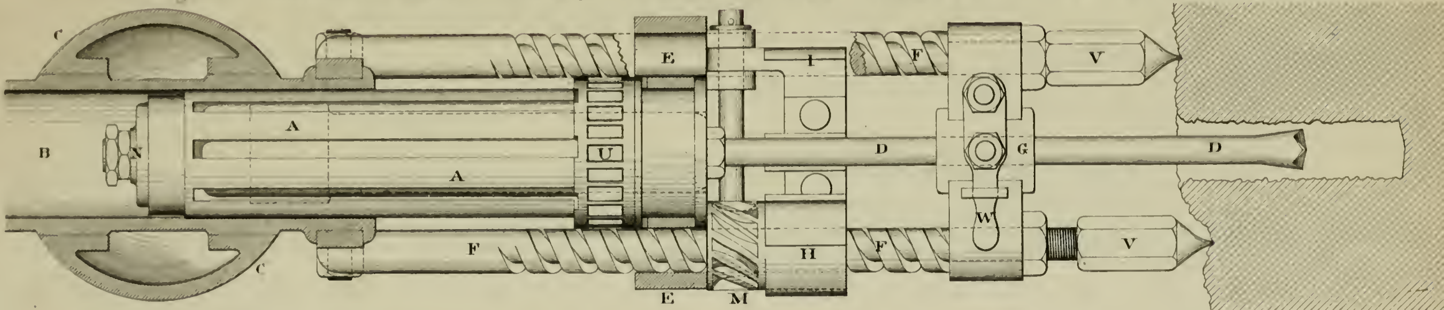
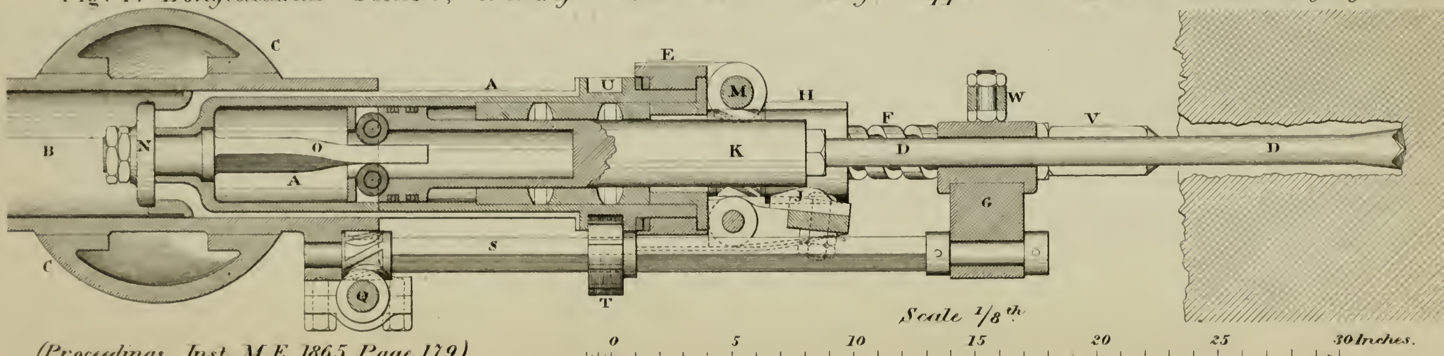


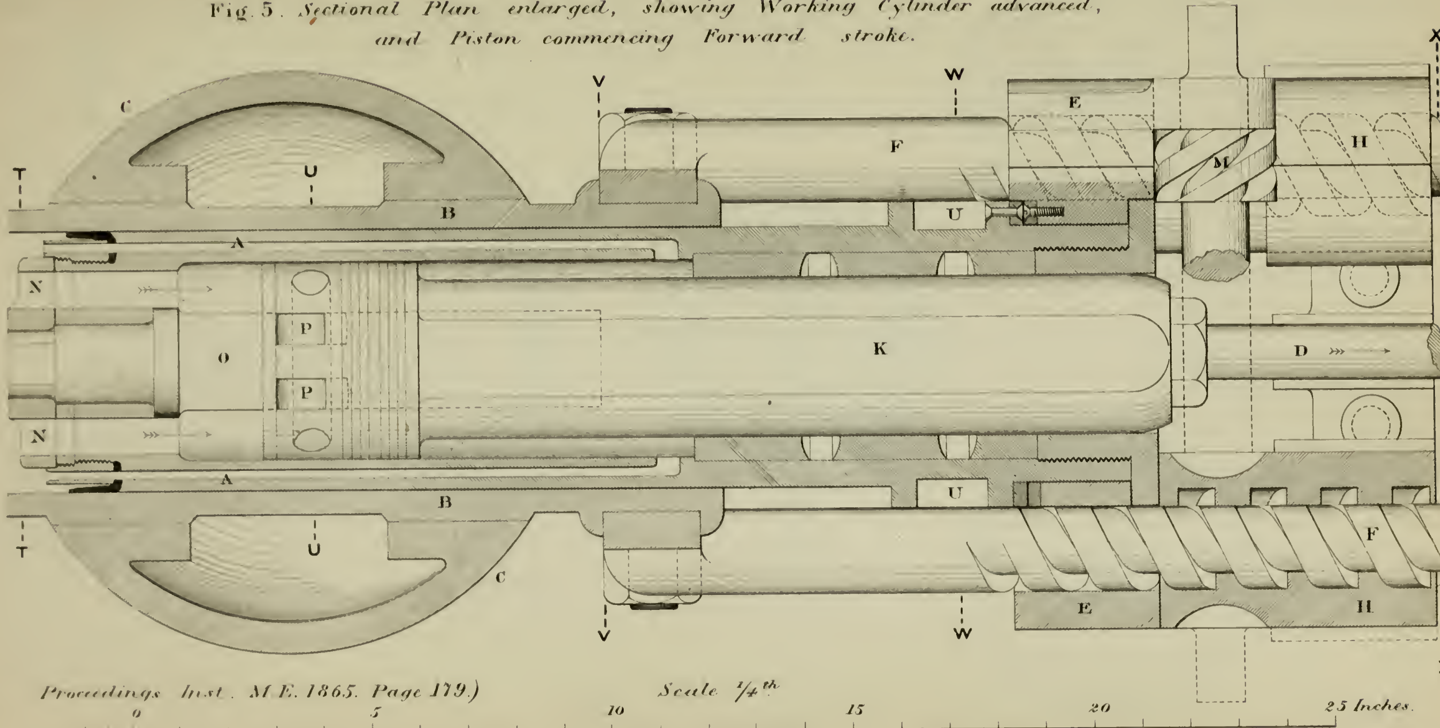
Fig. 4. *Longitudinal Section, showing Piston Rod striking Tappet for advance of Working Cylinder.*



(Proceedings Inst. M. E. 1865. Page 179.)

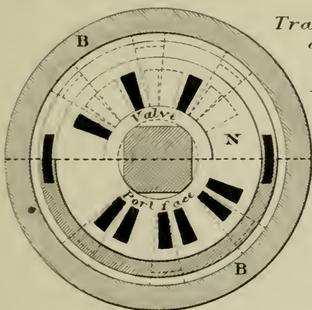
ROCK BORING MACHINE.

Fig. 5. Sectional Plan enlarged, showing Working Cylinder advanced, and Piston commencing Forward stroke.



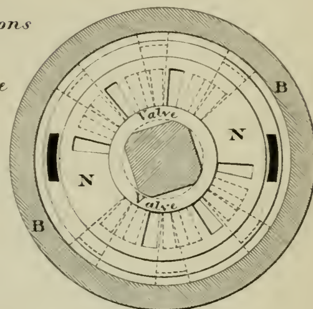
Transverse Sections enlarged (looking forwards).

Fig. 6. *Air Ports Open for Forward stroke.*



Transverse Sections at TT *(Fig. 5) showing Disc Air Valve and Ports.*

Fig. 7. *Air Ports Closed for Return stroke.*



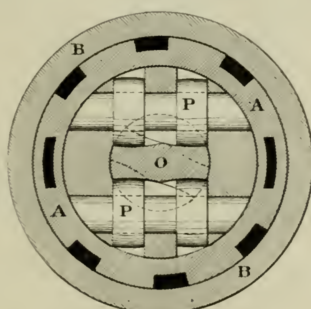
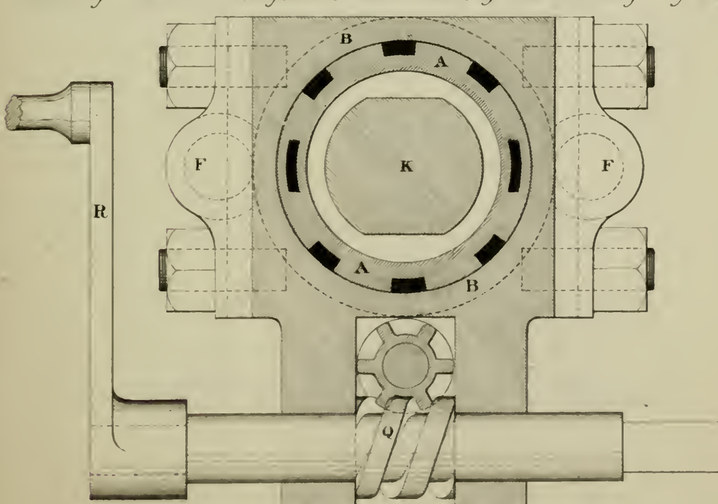


Fig 8. *Transverse Section at* UU *(Fig. 5) showing Rollers and Cam for turning Air Valve.*

Fig. 9. *Transverse Section at* VV *(Fig. 5.) showing Hand arrangement for rotating the Working Cylinder.*



Scale 1/4 th

0 1 2 3 4 5 6 7 8 9 10 11 12 *Inches.*

ROCK BORING MACHINE. *Plate 53.*

Transverse Sections enlarged (looking backwards).

Fig. 10. *Transverse Section at* WW *(Fig. 5.)*
showing Hand arrangement for rotating the Working Cylinder.

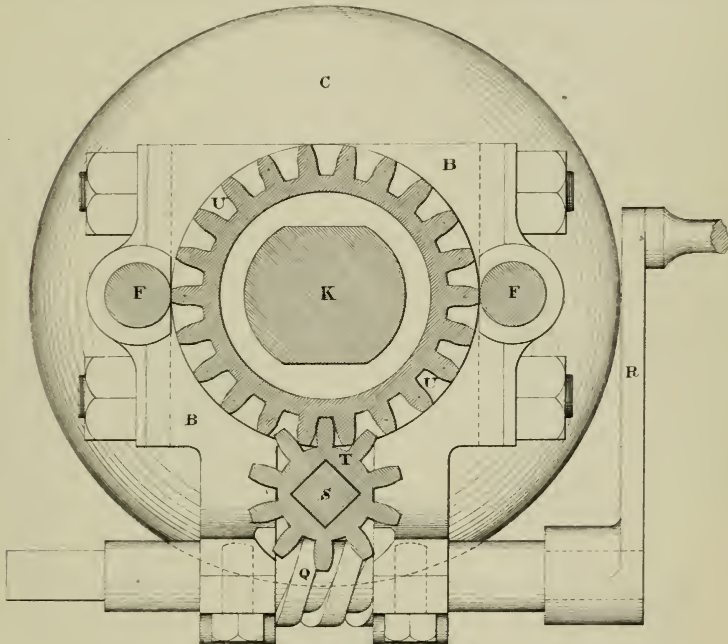
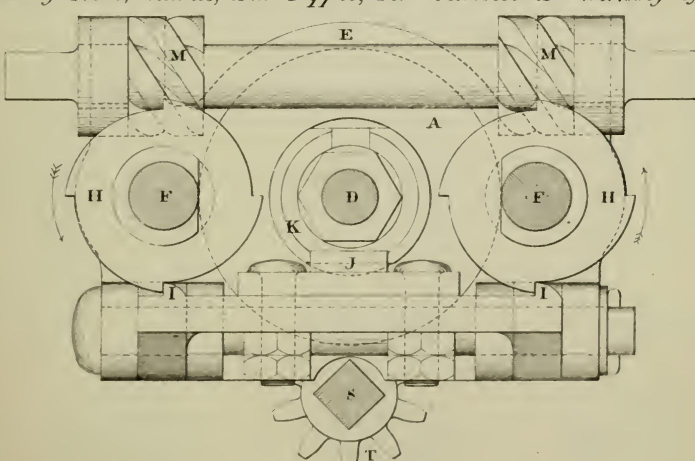


Fig 11. *Transverse Section at* XX *(Fig. 5.)*
showing Nuts, Catches, and Tappet, for advance of Working Cylinder.



(Proceedings Inst. M. E. 1865. Page 179.) *Scale ¼th*

0 1 2 3 4 5 6 7 8 9 10 11 12 *Inches*

ROCK BORING MACHINE. *Plate 54.*

Detail of Boring Tools, and mode of Fixing.

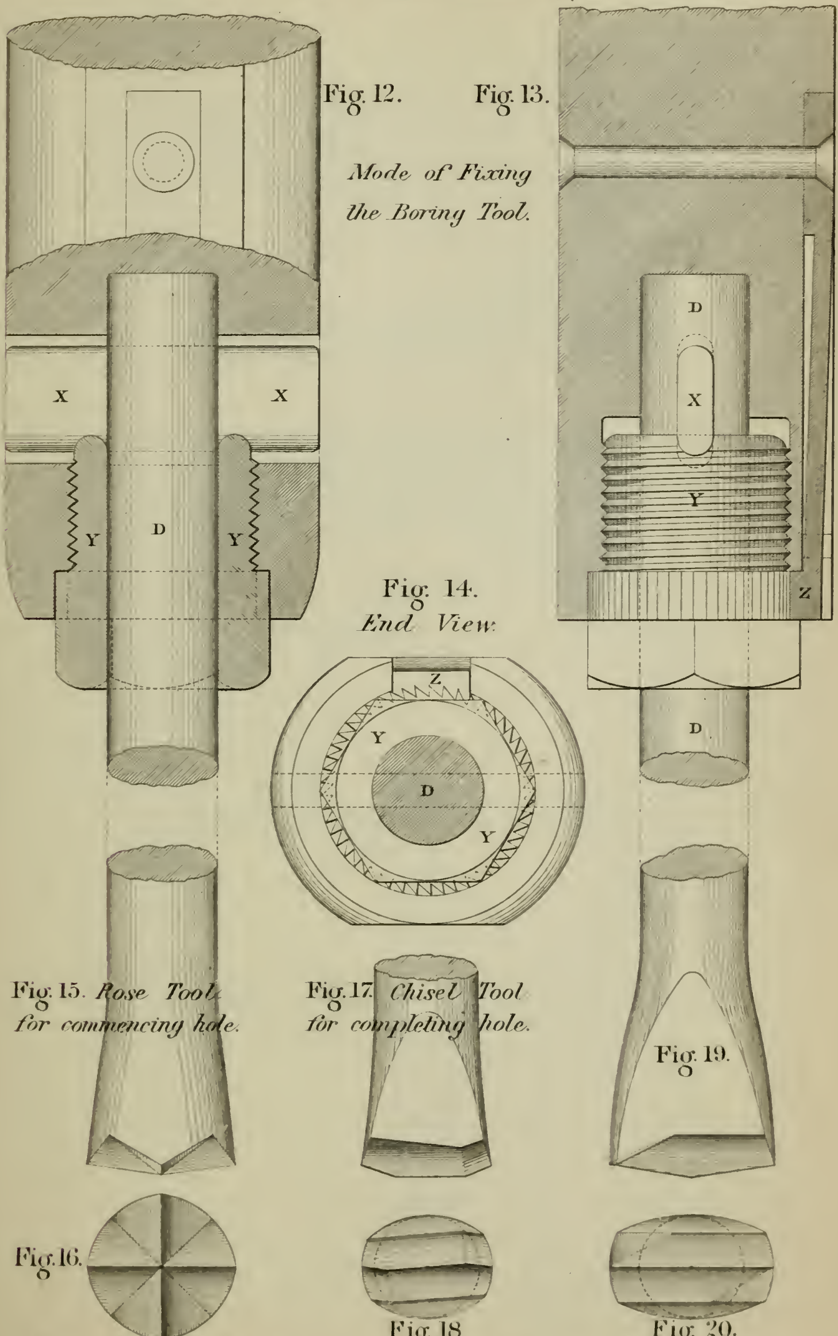


Fig. 12. Fig. 13. *Mode of Fixing the Boring Tool.*

Fig. 14. *End View.*

Fig. 15. *Rose Tool for commencing hole.*

Fig. 16.

Fig. 17. *Chisel Tool for completing hole.*

Fig. 18.

Fig. 19.

Fig. 20.

(Proceedings Inst. M.E. 1865. Page 179.) *Scale half full size.*

ROCK BORING MACHINE.

Sections of Roundwood Tunnel, showing Boring Machine in working position, with Frame and Carriage.

Fig. 21. *Longitudinal Section.*

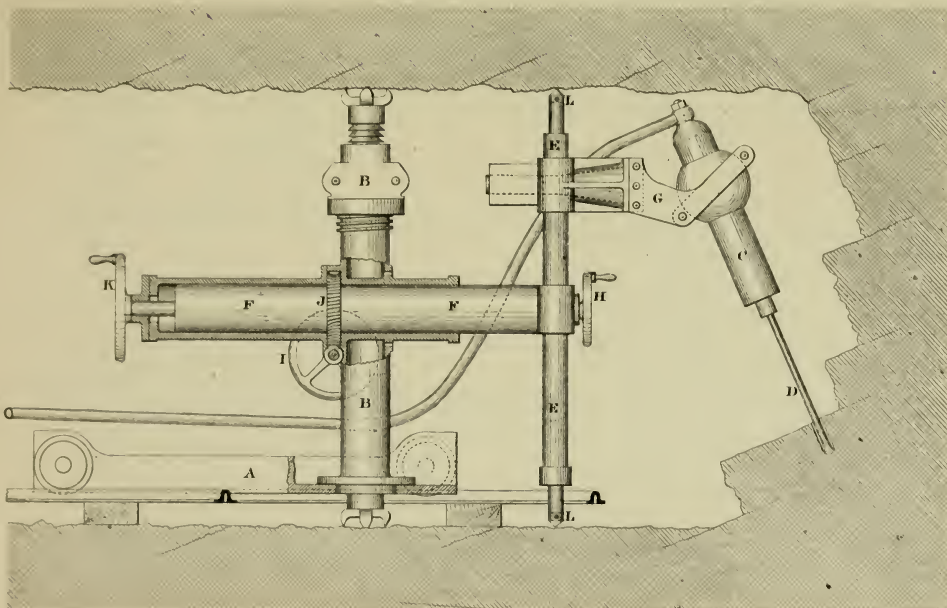
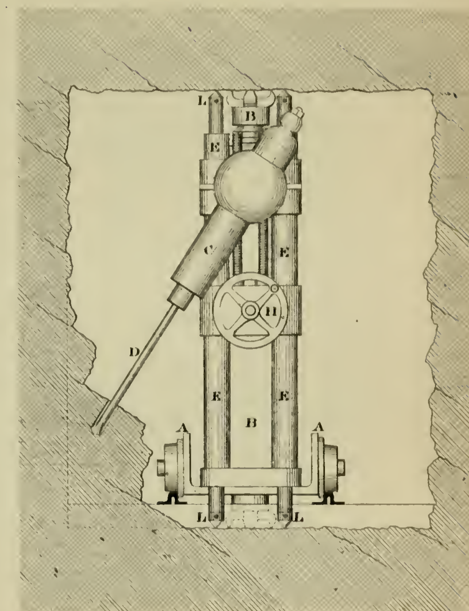


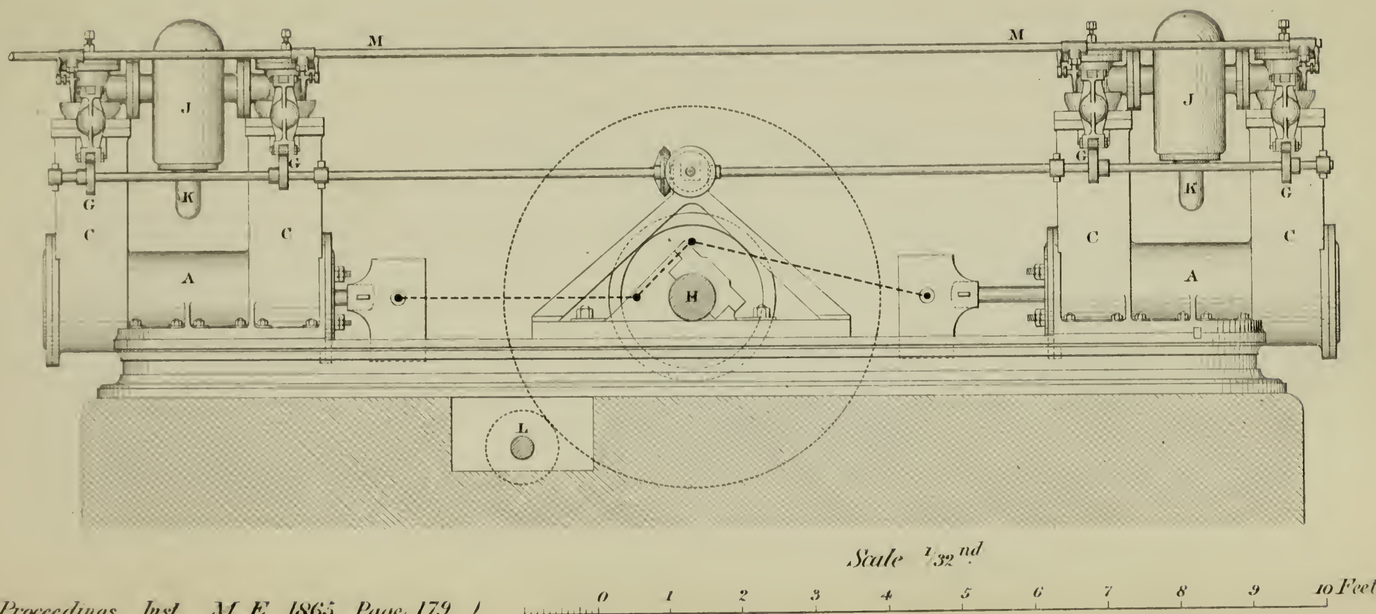
Fig. 22. *Transverse Section.*



(Proceedings Inst. M. E. 1865. Page 179.) *Scale 1/32nd* 0 1 2 3 4 5 6 7 8 9 10 Feet.

ROCK BORING MACHINE.

Air Compressing Engine.
Fig. 23. *Side Elevation.*

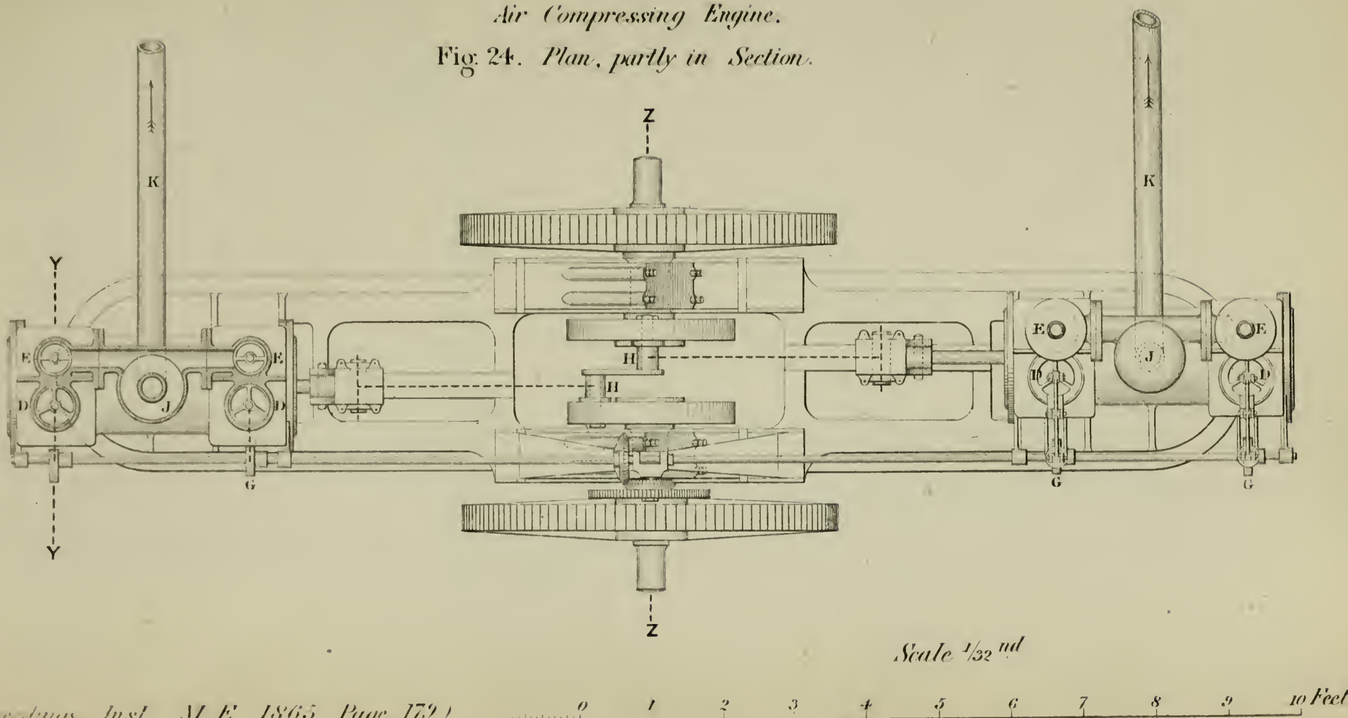


Scale $^1/_{32}{}^{nd}$.

ROCK BORING MACHINE.

Air Compressing Engine.

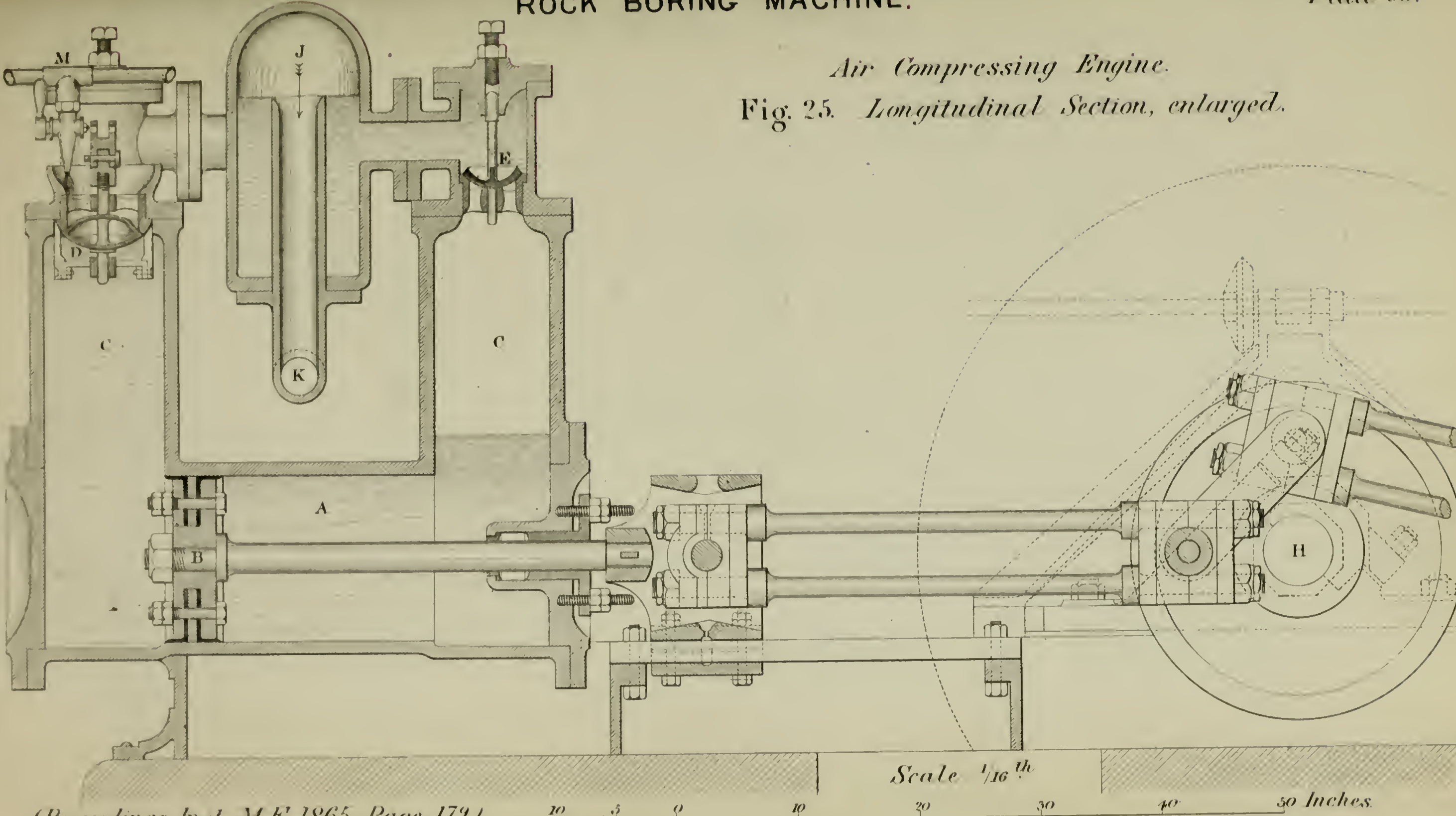
Fig. 24. *Plan, partly in Section.*



ROCK BORING MACHINE.

Air Compressing Engine.

Fig. 25. *Longitudinal Section, enlarged.*



(Proceedings Inst. M.E. 1865. Page 179.)

ROCK BORING MACHINE.

Air Compressing Engine.

Fig. 26. *Transverse Section at* **YY** *(Fig. 24.)*

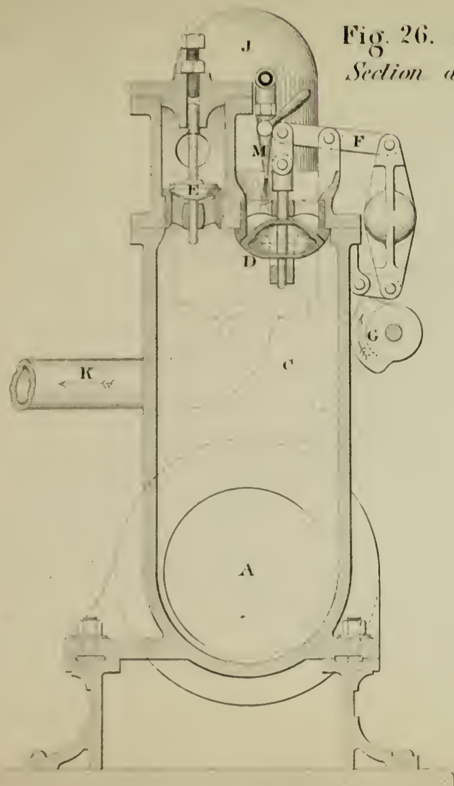
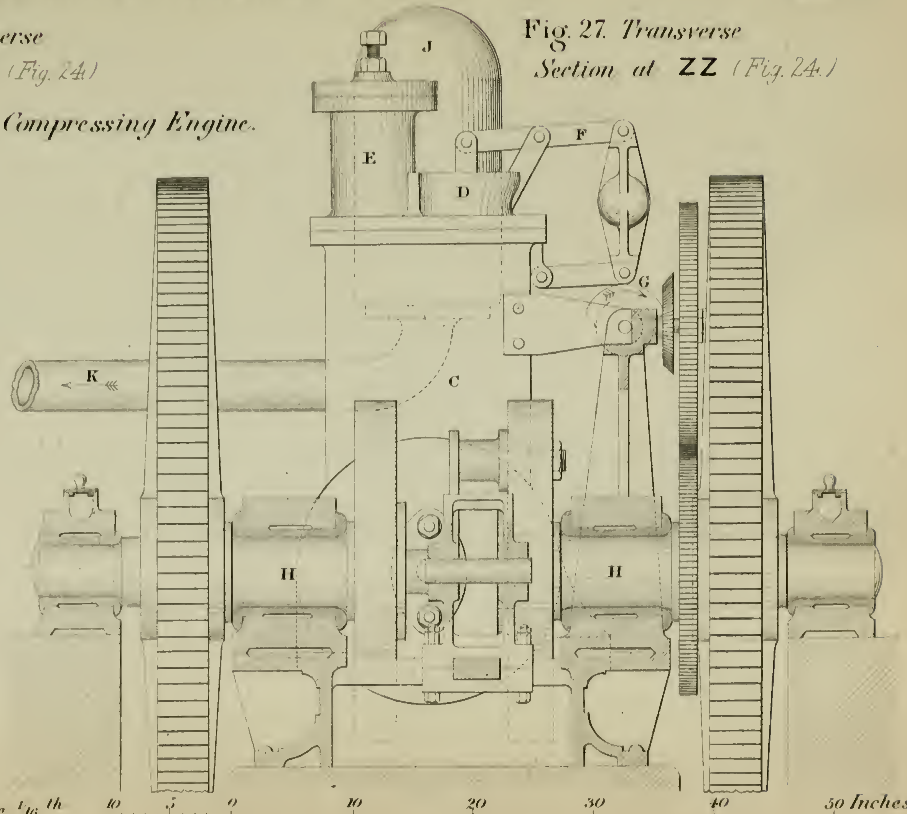


Fig. 27. *Transverse Section at* **ZZ** *(Fig. 24.)*



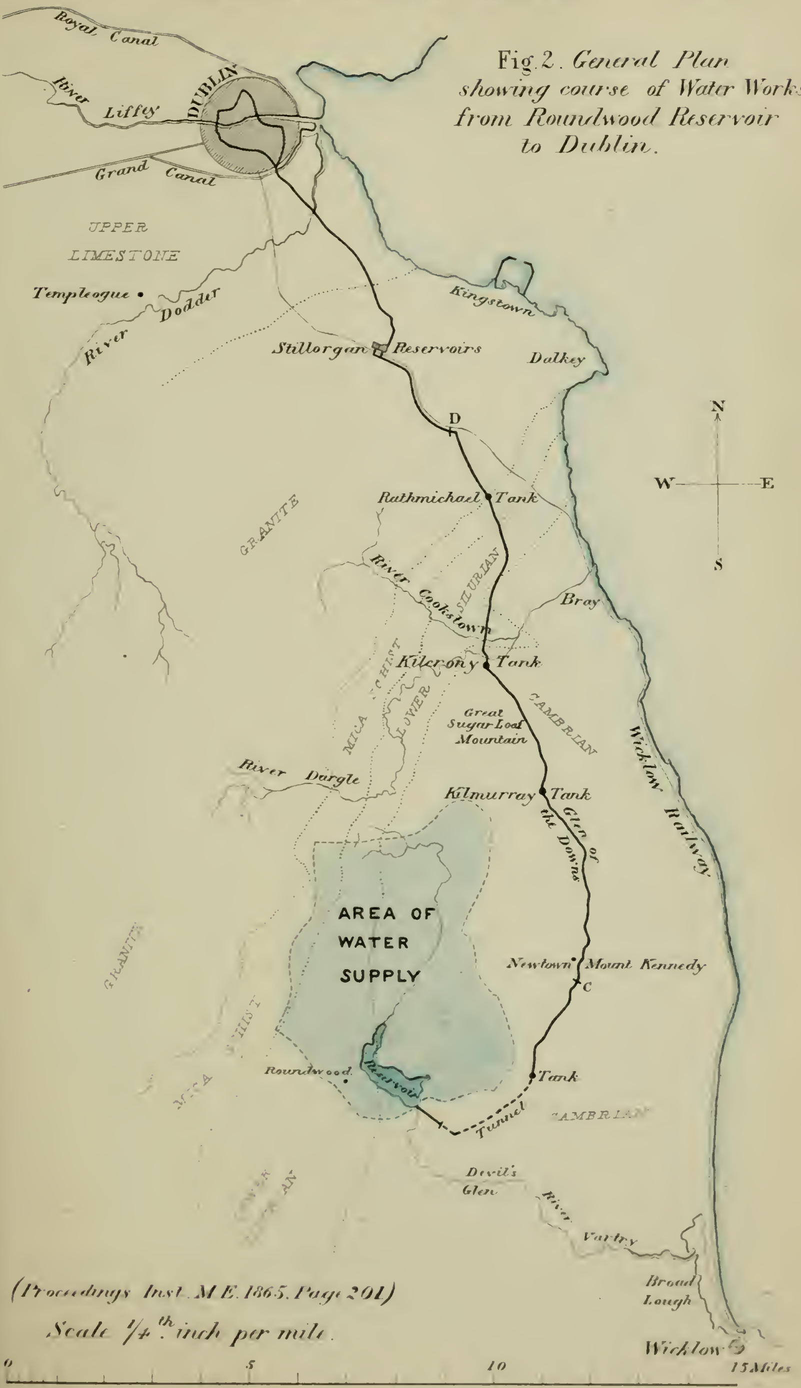
DUBLIN WATER WORKS. *Plate 60.*

Fig 1 *Plan of Drainage Area and Roundwood Reservoir.*

(Proceedings Inst. M.E. 1865. Page 201.)

Scale 3/4ths inch per mile

DUBLIN WATER WORKS. *Plate 61.*

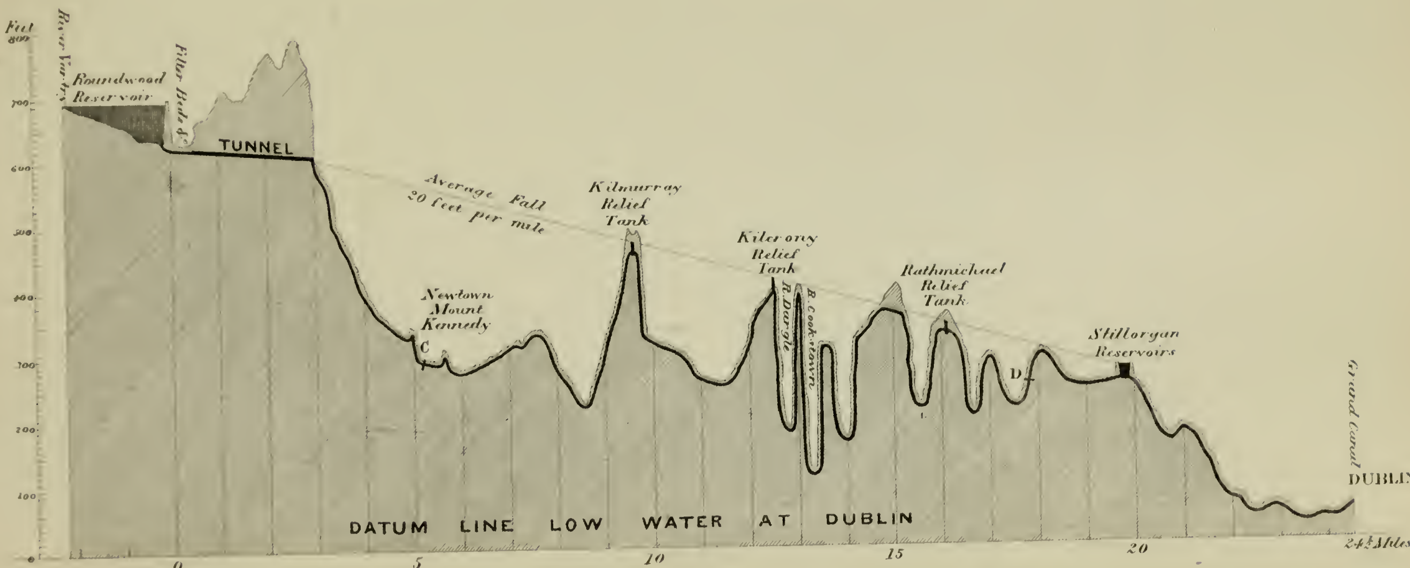


(Proceedings Inst. M.E. 1865. Page 201)

Scale 1/4th inch per mile.

DUBLIN WATER WORKS.

Fig. 3. *Longitudinal Section from Roundwood Reservoir to Dublin.*



Horizontal Scale 1/4th inch per mile.

(Proceedings Inst. M.E. 1865 Page 201.)

DESCRIPTION OF A ROCK BORING MACHINE.

By Mr. GEORGE LOW, of Dublin.

In driving a tunnel or quarrying in hard rock, the only method whereby the rock can be worked is by blasting; and the Rock Boring Machine forming the subject of the present paper has been constructed for the purpose of boring the blasting holes, with a view to facilitate and expedite the work by superseding the very slow and laborious mode of performing this operation by hand. The machine is driven by compressed air, and works a boring tool or jumper for boring the holes; and the boring tool works in a direct line with a self-acting reciprocating motion at a very high velocity, and is continuously turned round during its working, being made to rotate slightly between each blow.

The boring tool is fixed direct upon the end of the piston rod of a working cylinder; and this working cylinder moves within another exterior cylinder, in which it is made to rotate for the purpose of giving the rotating motion to the tool. The working cylinder has also a longitudinal forward motion within the exterior cylinder for giving the advancing feed to the tool, the working cylinder being propelled forwards by the compressed air that works the tool, thereby dispensing with the necessity for employing propelling gear, which is liable to break or get out of order and is subject to rapid wear. The exterior cylinder is carried by a spherical trunnion in a moveable radial arm or jib mounted on a travelling carriage, which gives the means of adjusting the boring tool to any desired direction and position, so that the holes may be bored in the most suitable directions according to the strata of the rock for the blasting to take the best effect in breaking up the rock.

This Rock Boring Machine, which is the invention of the writer, is shown in Figs. 1 to 11, Plates 49 to 53. Figs. 1 to 5 are sectional plans and longitudinal sections, showing the boring tool and working cylinder in different positions during the working of the machine; and Figs. 6 to 11 are transverse sections at successive points.

The machine is only 4 ft. 6 ins. total length, being made as short as possible in order that it may be moved in any direction in the tunnel, so as to enable it to be set to bore at any angle and in any position and direction that may be desired. The working cylinder A, Fig. 3, constructed of brass, is placed inside an exterior cylinder B of cast iron, which is fitted with a spherical trunnion C to support it in the radial jib or arm of the travelling carriage, as shown in Figs. 21 and 22, Plate 55. The inner cylinder A is free to move longitudinally within the exterior cylinder from end to end as it advances during the process of boring, as shown in Figs. 3 and 5; and it is also free to rotate within the outer cylinder, for giving the rotating motion to the boring tool D. The back end of the working cylinder A is packed with a cupped leather, shown black in Fig. 5, so as to be air-tight when moving within the exterior cylinder B. The front end of the working cylinder A fits into a wrought iron crosshead E, in which it is free to revolve; this crosshead is bored out on each side to slide upon the two screwed guide bars F F, which are bolted to the exterior cylinder B, Figs. 5, 9, and 10, and are carried forwards to the end bearing G of the machine. The guide bars F have a double thread of $1\frac{1}{2}$ inch pitch chased upon them from end to end, but the thread is planed off on the inner side of each screw down to the body of the guide bar, for the purpose of obtaining greater compactness in the construction of the machine, as seen in the transverse sections, Figs. 9, 10, and 11.

At the back end of the working cylinder A is the air valve N, Figs. 5 to 7, which is a circular disc valve with six inlet ports and six exhaust ports, as seen in Figs. 6 and 7. This valve is turned by a double spiral cam O, which is carried forwards into the end of the piston and piston rod K, and is acted upon by the four rollers P P, Figs. 5 and 8, bearing on both sides of the spiral wings of the cam.

The spiral wings are so sloped that as the piston moves backwards and forwards the cam is gently turned or twisted, carrying with it the air valve N fixed upon the spindle of the cam. The slopes of the cam are so arranged that the valve N opens the inlet ports for admitting the compressed air to act upon the large area of the piston, in order to make the forward stroke of the tool; and the valve is then turned so as to allow the air to exhaust again after the piston has struck the blow. The return stroke of the piston is produced by a constant pressure of the compressed air upon the small annular area of the front of the piston, the pressure for this purpose being maintained through the two ports shown in Figs. 5 to 9, which are always open. The exhaust air is discharged at the front end of the exterior cylinder B, being carried along grooves in the circumference of the working cylinder A, as seen in the plan Fig. 3, and the transverse sections Figs. 6 to 9.

The boring tool is caused to rotate by rotating the working cylinder A, the piston being prevented from turning in the cylinder by means of two flats planed on opposite sides of the piston rod K, which fit into corresponding flats in the stuffing-box of the cylinder, as seen in Figs. 5, 9, and 14. The rotating of the working cylinder A, with the piston and boring tool, is effected by hand by the worm Q, Fig. 9, which is turned by the handle R, Figs. 9 and 10, and gears into a worm wheel fixed on the square shaft S. The brass pinion T, Figs. 2, 4, and 10, slides upon the shaft S, and gears into the teeth U round the circumference of the working cylinder A, Figs. 3 and 10; so that by turning the handle R the working cylinder is caused to rotate; and as the cylinder advances at each turn of the nuts H, the pinion T slides forwards with it along the square shaft S, as seen in Fig. 4. In an earlier construction of the boring machine, having a pair of cylindrical trunnions instead of the present spherical bearing C, a self-acting rotating motion was obtained from the spiral cam O that works the disc air valve N, by prolonging the spindle of the cam through the back end of the exterior cylinder B; and a couple of pauls on the end of the spindle worked into a ratchet wheel on the end of the square shaft S, which was also prolonged backwards for the purpose,

in the absence of the spherical bearing C. In practice however it has been found preferable to rotate the working cylinder by hand by means of the handle R, as above described, because the very rapid reciprocation was very severe upon the self-acting rotating motion, making it liable to derangement; and the hand arrangement, besides having the advantage of simplicity, avoids the necessity of prolonging the shaft S backwards, and thus allows of adopting the spherical trunnion C, which gives increased facility for turning the machine into any position desired for boring the holes.

The crosshead E slides forwards along the two screwed bars F as the working cylinder A is advanced inside the exterior cylinder B during the process of boring; and in front of the crosshead the nuts H H are fitted on the screwed bars F, against which the crosshead and with it the working cylinder are pressed by the pressure of the compressed air behind the working cylinder A. The nuts H are held from turning, and thereby prevented from going forwards, by four projecting stops upon their circumference, Fig. 11, which are caught by the catches I I below; these catches are kept pressed up by springs against the underside of the nuts; and between the two catches is placed a tappet J, so curved that it may be struck by the end of the piston rod when the latter has reached the outer extremity of its stroke, as shown in Fig. 4.

The mode of action of this advance motion is as follows. The compressed air is admitted by the flexible pipe L into the exterior cylinder B behind the back end of the working cylinder A, which is thus kept pressed outwards against the crosshead E, while the crosshead is kept in its place and prevented from going forwards by the nuts H, and these are prevented from turning by the catches I. But when the boring tool D has advanced $\frac{3}{4}$ inch, the distance due to one quarter turn of the nuts H, the outer end of the piston rod K, which is allowed a range of $\frac{3}{4}$ inch variation in the length of its stroke, strikes against the tappet J, as shown in Fig. 4, and depresses it sufficiently to make the catches I I release the projections on the nuts H; the forward pressure of the working cylinder and crosshead against the nuts then causes them to slip

past the catches and advance one quarter turn, thereby moving forwards $\frac{3}{4}$ inch upon the screwed bars F, when the next projections on the circumference of the nuts are caught by the catches I. This process is repeated for every $\frac{3}{4}$ inch bored by the tool, until the nuts reach the front end of the screwed bars F.

By this arrangement the boring tool is allowed to advance at whatever rate it may be cutting in the rock. When the rock is comparatively easy to bore and the tool is cutting rapidly, the projections on the nuts slip past the catches from one to another rapidly, and consequently allow each successive $\frac{3}{4}$ inch advance to occur more quickly; whilst when the rock is harder and the tool is cutting slowly, there is so much longer an interval between each release of the catches, and the advance of the nuts is less frequent, thus admitting of a greater number of strokes being made by the boring tool for each $\frac{3}{4}$ inch length of hole bored.

For winding back the working cylinder A by hand, when required for the purpose of changing the boring tool, the two worms M M, Fig. 11, turned by a handwheel, are geared into the nuts H H, as shown in Figs. 1 to 5. The friction of the worms also acts as a break to prevent the nuts from turning too suddenly, as it causes them to move gently when the projections on the nuts are released by the catches I I at each $\frac{3}{4}$ inch advance of the boring tool.

As the working cylinder A and crosshead E only press loosely forwards against the nuts H, neither the nuts nor the screwed bars F receive the slightest portion of the concussion from the blows of the tool; but the shock of each blow is conveyed direct to the air cushion behind the working cylinder A, in the back end of the exterior cylinder B. This effectually prevents crystallisation of the portions that are exposed to the direct concussion of the blow, and prevents any loosening of the several parts of the machine; it also relieves the carriage frame from the full shock of the blow, and steadies the boring cylinder.

At the outer end of the two guide bars F F are two screwed caps V V with steel points, Figs. 1 and 3, for the purpose of steadying the end of the machine against the rock. The outer end

of the boring tool D is steadied in the front bearing G, across the end of the two guide bars F, in order to compel the tool to bore straight when it meets with extra hard rock or quartz veins inclined to the direction of the hole; and by turning the handle W, the top bearing or step can be readily lifted out when the boring tool requires taking out for changing. During the working of the tool a jet of water is kept constantly playing into the hole; and this aided by the reciprocation of the tool effectually clears out all the loose material as fast as it is detached by the tool, without ever requiring the tool to be withdrawn as in hand labour for the purpose of clearing out the hole. In one of these boring machines working in the Roundwood Tunnel of the Dublin Corporation Water Works, the water is obtained from the top of the tunnel shaft, being a portion of that raised by the pumping engine which drains the tunnel, and the jet is thrown into the bore hole under a pressure of about 80 lbs. per square inch.

The mode of fixing the boring tool D in the piston rod K is shown in Figs. 12, 13, and 14, Plate 54, drawn half full size. The fixing of the tool is a very important point in the working of the machine, in order to ensure a thoroughly secure fixing and at the same time the means of readily and quickly changing the tool. The tool D is dropped into a socket in the end of the piston rod K, and the parallel cotter X being then passed through is fixed by the screwed gland Y, which presses the tool home to the bottom of the socket and secures the cotter endways by entering into the two notches in the front edge. The gland Y is prevented from turning back by a ratchet and spring Z; and for releasing the tool the spring is held back by a stud while the gland is unscrewed.

Several different forms of Boring Tools have been tried with the machine, but the results of experience have led to the adoption of the two forms only that are shown in Figs. 15 to 18, Plate 54, drawn half full size. The rose tool, Figs. 15 and 16, having two chisel edges at right angles to one another, is found the best form for commencing the hole and boring the first 9 or 10 inches length. The shape of this tool, in conjunction with the continuous rotary motion given to it between each stroke, prevents it from being led

away sideways when it meets with a vein of quartz harder than the rest of the rock and lying much inclined to the direction of the hole. The second tool, Figs. 17 and 18, used for completing the hole, is a chisel formed with the cutting edge in three bevils a little inclined to one another in both directions. The chisel shown in Figs. 19 and 20 was found the best for boring straight, but it could not be made to stand well, and was consequently abandoned. A hollow tool has also been tried, into which was inserted a water jet; and the exhaust air from the cylinder was also turned into it, which blew the water out from the point of the tool into the hole with considerable force. This was found a most excellent plan for keeping the hole clean; but in consequence of its complication and the liability of the jet orifice to become choked up with deposit from the water employed, it was abandoned and the separate water jet already described has been substituted.

The Frame and Carriage for this boring machine are shown in Figs. 21 and 22, Plate 55. The traversing carriage A is made very low, in order to allow of readily removing the debris from blasting; and upon it is mounted the upright pillar B, capable of swivelling round upon the carriage and having means for clamping it securely between the top and the bottom of the tunnel. The working cylinder C with the boring tool D is carried by the transverse frame or rest E upon the extremity of the horizontal jib F projecting from the centre pillar B. The arm G carrying the boring cylinder C can be traversed into any position in the frame E by means of a screw motion worked by the handwheel H; while the frame E can itself be turned round upon the axis of the horizontal jib F by the handwheel I working the worm wheel J, and the jib F can be lengthened or shortened by the handwheel K. By this means the boring cylinder C can be adjusted to any part of the face of the tunnel; and the spherical trunnion by which the boring cylinder is carried in the arm G allows of its being placed to bore in any position and direction. These several adjusting movements enable the tool to bore the holes in the exact line the miners may wish to place the shot, as the boring cylinder can work

either upwards, downwards, sideways, or at any inclination; and all the movements are at all times central and within easy reach of the attendant, whatever may be the direction or position of working.

The transverse frame or rest E is provided at each end with a pair of projecting steel points L L, which can be lengthened or shortened so as to clamp the rest securely against the rock, thereby relieving the horizontal jib F and the pillar B from the shocks produced by the blows of the boring tool. The steel points L L are attached to pistons inside the columns of the rest E, and by admitting the compressed air between the pistons the points are caused to strike out against the sides of the tunnel, and are then secured by self-locking catches. It is generally found sufficient however simply to wedge the hind wheels of the carriage in order to render the whole perfectly steady, without any necessity for clamping the carriage and rest against the rock.

The compressed air for working the boring machine is supplied by an Air Compressing Engine at the top of the shaft, driven by a small portable steam engine. The air compressing engine is shown in Figs. 23 to 27, Plates 56 to 59, and consists of two horizontal compressing cylinders A A, Fig. 23, fitted with air-tight pistons B packed with brass rings or cupped leathers, Fig. 25. On each end of the cylinder A are upright chambers C C, and on the top of each chamber are a pair of inlet and delivery air valves, so that there are two inlet valves D D and two delivery valves E E to each compressing cylinder; these valves are circular, and fit air-tight upon conical faces, as seen in Figs. 25 and 26. The four inlet valves D D are each suspended from a lever F, and in the original construction there was simply a weight on the outer end of the lever to cause the valve to shut when the piston B had drawn in sufficient air to fill the chamber C; it was found however that the valves did not work very steadily with the levers and weights, and they also shut before the piston reached the end of the stroke, so that part of the stroke was wasted in uselessly expanding the air in the chamber C. A cam G, Fig. 26, worked from the crank shaft H, was therefore added to each of the valve levers F, and the cam opens the inlet

valve at the commencement of each forward or suction stroke of the piston, and keeps it open till the commencement of the return or compressing stroke, when the valve is shut suddenly by the weight; and this arrangement has proved quite satisfactory. The delivery valves E E are shut by the back pressure, as soon as the compressed air is all forced out of the chambers C; they deliver the air into the air-vessels J, which are for the purpose of equalising the pressure of the air under the varying pressure of the stroke. A pipe K from each of the two air-vessels conveys the compressed air to a large wrought iron receiver, from which it is supplied for working the boring machine.

The two air-compressing cylinders A A, Figs. 23 and 25, are each 14 inches diameter with 18 inches length of stroke, and are placed at each end of a cast iron bed-plate; the pistons are worked by connecting rods from the double cranks H at right angles to each other, which receive motion from the countershaft L driven by the steam engine. By employing two cylinders of half area each for compressing the air, worked by cranks at right angles to each other, instead of a single larger cylinder, an advantage is gained in delivering the compressed air to the receiver more uniformly, and also the strain on the working parts is more evenly divided. The cylinders A are filled with water, which rises at each stroke to the top of the upright chambers C C, and the surplus water is forced through the delivery valves E, the object being to fill up every space with water at the end of the stroke, and so ensure every particle of air being forced through the delivery valves. To allow for leakage and waste of water, a supply is kept constantly flowing into the inlet valves D from the small pipe M, regulated by a tap; and the water forced through the delivery valves at each stroke keeps the air-vessels J J constantly filled with water up to the mouth of the pipe K, so that the compressed air is kept quite cool. The surplus water passing into the pipe K slowly accumulates in the large air receiver, out of which it is discharged occasionally.

The crank shaft H is driven at 22 revolutions per minute, and at each stroke the piston draws in the air through the inlet valve at one end of the cylinder, and compresses the air to six atmospheres

or 90 lbs. per square inch at the other end of the cylinder, discharging the compressed air through the delivery valve to the receiver. The minimum pressure maintained in the air receiver is 75 lbs. per square inch, and the maximum 125 lbs., the average being about 85 lbs. per square inch. From the receiver the compressed air is conveyed by cast iron pipes with india-rubber joints up to within 50 feet of the boring machine. It is then conveyed to the machine through an india-rubber pipe made with six-ply canvass and about 100 feet long, which allows the boring machine to be advanced or drawn back without undoing a single joint.

This boring machine is now employed in the construction of the Roundwood Tunnel for the new Dublin Corporation Water Works, of which a longitudinal and transverse section are shown in Figs. 21 and 22, Plate 55, where it bores the holes for blasting at one of the working faces. The tunnel is rectangular, 5 feet wide and 6 feet high, and is being carried through Cambrian rock of a remarkably hard and difficult character, interspersed with quartz veins. Six shot holes of 20 inches depth are usually fired at each blast, and these six holes of $1\frac{3}{4}$ inch diameter are all bored by the machine in about $3\frac{1}{2}$ hours; two chisels are used for each hole, which require fresh grinding before using again. With handwork however each of the same holes takes $2\frac{1}{2}$ to 3 hours for drilling, and requires usually about fifteen fresh tools before it can be completed. The practical value of this remarkable saving of time that is effected by the use of the machine is specially experienced in such work as tunnelling or other rock-blasting, where saving of time is generally of such great importance both in expediting and economising the work. The average rate at which the very hard rock is bored by the machine at the Roundwood Tunnel is about one inch per minute; and it has been found as the result of experience with the machine that it bores quicker and keeps the edge on the tool better by striking with less force of blow but with greater rapidity. The number of blows has been increased from 250 to 500 or 600 blows per minute, and the result is that one hole is now bored with two tools without

re-sharpening, instead of using five or six tools as formerly; and with one tool a hole of 26 inches depth is bored in the Dalkey granite without re-sharpening.

The following are the results of working in the Dalkey granite:—

1st	hole	24½	inches	deep	in	11	mins.	10	secs.
2nd	„	19½	„	„		14	„	...	„
3rd	„	9	„	„		5	„	55	„
4th	„	4½	„	„		2	„	10	„
5th	„	9	„	„		7	„	35	„
6th	„	9	„	„		5	„	25	„

The following are the results of working in the remarkably hard rock of the tunnel at Roundwood:—

1st hole	8½	inches	depth in	3½	minutes.
	6	„	„	8	„
	9	„	„	3	„
Total ...	**23½**	„	„	**14½**	„
2nd hole	12	„	„	8	„
	9	„	„	4	„
Total ...	**21**	„	„	**12**	„
3rd hole	6	„	„	5	„
	9	„	„	10	„
Total ...	**15**	„	„	**15**	„
4th hole	10	„	„	6	„
	9	„	„	3	„
Total ...	**19**	„	„	**9**	„
5th hole	10½	„	„	4	„
	8	„	„	4½	„
Total ...	**18½**	„	„	**8½**	„
6th hole	**14**	„	„	**10**	„

The average rate at which the machine now bores is, for the first portion of the hole, 10 and 11 inches depth in 4½ to 8 minutes; and for the second portion, 9 and 9½ inches depth in 3 to 3½ minutes.

The following special points of advantage have been experienced in this boring machine; and these may be considered as essential conditions to be fulfilled in a good machine for the purpose of

boring in hard descriptions of rock, and for standing satisfactorily the special wear and tear to which such machines are necessarily subjected.

The boring part of the machine with the tool is made very short, so as to allow it to work in any direction and position in the tunnel, in order that the blast of the hole bored may displace the largest amount of rock. The carriage frame carrying the working cylinder is also very compact, occupying little space and allowing the cylinder to be quickly adjusted into any desired position.

The reciprocating parts are very few in number, and are in the direct line of the blow; these are only the piston and rod in one piece of steel, and the tool secured in the piston rod so as to allow no play. Moreover in order to prevent crystallisation of the parts exposed to the direct concussion, a cushion of air is provided at the back of the working cylinder, which also relieves the carriage frame from the shocks of the blows. Also the tool being made to reciprocate with the piston, the hole is more easily kept free from the debris than when the tool is stationary and receives blows from a detached piston, as in other constructions of boring machines; and the strong water jet playing into the hole is found to keep it quite clear during the process of boring.

The advance of the tool is self-acting, and exactly at the same rate that the tool is cutting, however variable may be the nature of the rock; and whether the tool is cutting at the rate of 3 inches per minute in one part of the hole or only 1 inch per minute in another part, the advance given to the tool is exactly at the same rate that the boring progresses in each case; so that there is no risk of the piston at any time working beyond its proper range of stroke and striking the cylinder cover. The advance motion for the tool is obtained from the pressure that drives the piston, without the use of propelling gear, the absence of which greatly increases the durability of the machine. The turning motion for the tool also being connected to the stationary outer cylinder is freed from the source of derangement that would arise from the rapidity of the blows of the tool if the turning motion were connected to the reciprocating part. The motion for working the

valve is gradual and easy in its action, so that a very rapid action is obtained without any destructive shocks. The outer end of the tool is guided in a bearing, to prevent it from working to one side and getting jammed when meeting with an oblique vein of harder material.

The machine is arranged so that it can be brought to work again immediately after a set of holes have been blasted and before the debris is removed, which can be done whilst the machine is at work, the material being carried or thrown through the clear space left by the carriage frame ; and a jet of air being left open near the face at the time of explosion soon dilutes and clears off the gases resulting from the explosion of the powder. This saves much of the loss of time which occurs with other machines in removing the debris before the machine can be set to work again. The compressed air on being discharged from the boring cylinder also serves effectively to ventilate the workings, and supplies fresh air to the miners.

Mr. Low exhibited specimens of the different sorts of boring tools used in the machine, and also samples of the hard Cambrian rock through which the tunnel was being driven, showing the quartz veins with which the rock was intersected.

The President thought there must be a good deal of difficulty in boring through such hard rock with the machine, from the tools requiring to be sharpened very frequently, and he enquired how often they were found to need sharpening in regular work.

Mr. Low replied that the tools required to be sharpened on the average for every 9 inches length of hole bored, on account of the particularly hard nature of the rock.

Dr. Downing said that through the kindness of the engineering staff and the contractor he had seen the boring machine at work in the Roundwood Tunnel, and had been enabled to collect a few data as to its action. As regarded the rapidity of boring the

holes, which was of course an essential consideration, he believed that 1 inch per minute might be taken safely as about the rate of the actual boring. He had seen a hole 20 inches long bored in 22 minutes, with boring tools $1\frac{3}{4}$ inch diameter like the specimens exhibited, and the same length had also been done in 18 minutes; and 20 inches in 20 minutes might be taken as the average rate of boring. It was not very easy to ascertain the exact time occupied per hole so as to include all the shifting of the machine, &c.; the practice was to draw the machine back after six or seven holes had been bored by it, and then a few more holes were made by hand in those parts of the face of the heading where the machine could not readily be worked; and all the holes were then fired nearly simultaneously. Including all these operations he believed 45 minutes for each hole would be a fair average to take for all the holes, including both those bored by the machine and by hand labour.

The President enquired how the hole was cleared out during the boring, and how often the tool had to be withdrawn for the purpose.

Dr. Downing replied that the tool was never withdrawn for the purpose of clearing the hole, which was cleared out by letting a jet of water under a high pressure play constantly into it during the working of the machine, and the water assisted by the reciprocation of the tool cleared out all the loose material as fast as it was detached by the tool. This was done much more effectually than by the ordinary mode of occasionally scraping out the hole when manual labour was used. The tool was usually withdrawn at about every 7 inches length bored, for the purpose of inserting a longer boring tool, the nuts upon the screwed guide bars being set back by hand. Before firing the charges in the holes the machine was drawn back to a sheltered spot, the distance varying with the progress of the work; at the time when he saw the machine working it had to be drawn back about 50 or 60 feet from the working face to the place of shelter. The machine ran upon a tramroad, and was drawn back very quickly, so that there was very little time lost in moving it.

Mr. H. W. Harman enquired what was found to be the comparative economy of the machine in working as compared with hand labour.

Dr. Downing said the time that the machine had been at work and the circumstances of the situation in which it was employed hardly admitted of any decided result being arrived at yet as to its economy; at present the cost of working with the machine appeared to be about equal to that of hand labour.

Mr. H. W. Harman enquired whether the present was the first application of the machine, and what was its cost.

Dr. Downing replied that the present work was the first application of the boring machine in regular work, and the machine now in use was the third that had been made, containing several improvements upon the two previous ones. Five more of the machines were now being constructed he understood, which were all intended to be employed upon the Roundwood Tunnel. The cost of the machine itself with its carriage was about £225, and the cost of the air-compressing engine about £210.

Mr. E. Leigh enquired how much rock was removed per day in the tunnel by the aid of the boring machine.

Dr. Downing said the quantity of rock removed per day varied greatly, as it depended upon the hardness of the rock, which was very variable; but he did not know the actual quantity.

Mr. W. E. Newton remarked that one of the advantages of the present machine appeared to be the ingenious arrangement for the advance of the boring tool, whereby the tool was advanced exactly according to the rate at which the work progressed. With any direct mechanical connection, such as a crank motion or an ordinary feed motion, the tool would be advanced a definite distance at each blow, and neither more nor less under any change of circumstances; but in the present machine, by means of the self-acting nuts and screws governing the advance of the working cylinder, the total advance of $\frac{3}{4}$ inch allowed by the turning of the nuts might be obtained after a very few strokes; or, if the rock were too hard to admit of so rapid an advance, any number of blows might be given by the tool for each $\frac{3}{4}$ inch advance, the tool continuing to drive

away at the rock until it reached the end of the $\frac{3}{4}$ inch feed, and then the turning of the nuts allowed a further $\frac{3}{4}$ inch advance. By this means the tool was always advanced the right distance, just as in hand work, so as to follow up the work constantly according to the hardness of the rock; and the whole of the advance motion was entirely self-acting, without requiring the attention of the man in charge of the machine.

He enquired whether the expansion of the compressed air liberated from the cylinder of the boring machine was found to be attended with any disadvantage, by freezing the moisture in the exhaust passages.

Dr. Downing replied that no trouble had been experienced from the expansion of the compressed air, and the cold air thereby supplied at the working face was found a great advantage to the men in the tunnel by the thorough ventilation which it produced.

Mr. T. Waterhouse enquired what was the weight of the boring machine, and whether it was applicable also to sinking vertical shafts.

Mr. Low replied that the weight of the machine was about 2 tons including the carriage; and it could be employed for sinking a vertical shaft, in which case the weight would be only about 30 cwts. including the frame.

Mr. J. Murphy remarked that the frequency with which the boring tools required sharpening would depend much upon the quality and temper of the steel employed; and perhaps a harder quality of steel might be procured for the purpose, which would stand for a longer time without sharpening. He understood steel was now made of such superior quality as to be capable of cutting and turning steel tyres after hardening; and if that were tried for the boring tools it would probably save much of the trouble of sharpening them. The form of the boring tools employed in the machine appeared new, as he had not seen that form used in boring by hand; and the peculiar shape might perhaps account in part for the greater durability of the tools when worked by the machine than in hand work, since the shape of the tool had no doubt a great effect on the efficiency

with which the work was done; but if the same shaped tools were employed with the machine and by hand he did not understand why they should be found to require sharpening so much less frequently with the machine, as the action upon the tool appeared very similar in both cases. In the present machine there was some appearance of complication, arising probably from the number of small parts of which it was composed; but the utility of a boring machine when applied for sinking vertical shafts had been strongly exemplified at Cardiff, where one of Messrs. Mather and Platt's boring machines had been employed with great success to bore for water. That machine bored a well of 18 inches diameter at the rate of 20 to 30 feet per week to a depth of 295 feet, chiefly through the old red sandstone rock, from which excellent water was obtained; and the well now yielded a supply of about 500 gallons per minute, which was used for brewing purposes. Another of the same machines had been employed also at Middlesbrough to bore for coal, and had bored a hole of 22 inches diameter part of the way and afterwards 18 inches diameter to a total depth of 1300 feet through new red sandstone; and he had no doubt the machines would soon be brought into practical operation for various purposes. Had the practicability of sinking wells in that ready manner been demonstrated earlier, it might perhaps he thought have been expedient to try boring for water in the immediate neighbourhood of Dublin, before bringing it in from so great a distance as Roundwood.

Mr. J. Andrews, resident engineer upon the works in progress of the Dublin Water Works, remarked that, in reference to the relative durability of the boring tools when worked by the machine and by hand, the cause of the tools requiring less frequent sharpening with the machine was probably to be found in the fact that the tool being attached to the piston in the working cylinder gave the blow on the rock and was itself the hammer; it was also guided with precision in the blow, and turned with regularity, so that the point or chisel struck with a solid and even bearing in the bottom of the hole. Moreover the force of the blow was given to the tool by the compressed air behind the piston in the working cylinder,

which had not the damaging effect upon the tool occasioned by the dead blow of a hammer. In the latter case not only did the hammer soon destroy the end of the tool on which it struck, but the chisel end also was soon rendered useless by the unsteadiness with which it was held and turned by the hand, the blow being given when only a corner of the chisel touched in the bottom of the hole, which caused the sharp edge to be chipped and broken by a few strokes. The length of stroke of the tool in the machine was about 4 inches, and the lighter blow given by it at each stroke as compared with hand work was more than made up for by the very much greater rapidity of the strokes with the machine, whereby the hole was bored in a shorter time and with less injury to the tools.

The PRESIDENT enquired what was the rate of advance of the tunnel per day at the part where the machine was now working; and what had been found to be the practical advantage of boring by the machine as compared with hand labour.

Mr. J. ANDREWS replied that in the very hard lower Cambrian rock in which the machine was now working the rate of advance of the tunnel was from 6 to 8 inches forward per day, the size of the tunnel being about 6 feet high by 5 feet wide. With regard to the comparative advantage of boring by the machine or by hand, he had seen a hole of from 20 to 24 inches depth bored by the machine in from 15 to 20 minutes in a part of the rock not intersected by quartz veins, and three tools only were required to perform this work; but to do the same work by hand labour would have required two men for about 2 hours, and would have taken as many as from 20 to 30 or even 40 tools. The expense of boring by the machine was about equal to that of hand labour, but the machine had not yet been at work long enough to do more than about 12 or 15 yards of direct work.

The PRESIDENT enquired whether by putting a sufficient number of men upon the work the tunnel could be driven as fast by hand labour as by the machine.

Mr. J. ANDREWS said there was so little room for working at the face of the rock, on account of the small size of the tunnel, that the machine would bore more holes in a given time than it

was possible to do by hand labour under any circumstances. Notwithstanding this advantage however the actual rate of advance of the tunnel had not been greater since the machine was used than before its employment. This was on account of the small size and rectangular form of the tunnel not admitting of the full benefit being derived from the machine, as much of the work in getting out the corners had still to be done by hand; and much time was taken up in shifting the working parts into new positions, hammering off the shaken rock, and getting the debris out of the way. Moreover the frame of the present machine was found rather clumsy in the confined space of the tunnel, and a smaller frame which was now being made, better adapted to the situation, would enable the work to be carried forwards much more rapidly.

Mr. J. Murphy enquired what was the difference between the machine now described and that employed for excavating the large Mont Cenis tunnel between France and Italy, which he understood was advancing at the rate of about 3 feet per day.

Mr. J. Andrews believed the boring tools were similar in the two machines, but the Mont Cenis machine consisted of a large frame carrying eight boring cylinders and tools working independently by compressed air; an adit was driven by this means 9 feet square, and the whole size of the tunnel was afterwards completed by hand labour to about 26 feet by 24 feet. As many as 80 holes 3 feet deep were bored in the adit face before blasting. Each boring part of that machine could only work horizontally, and was longer and larger than in the present machine, in which the boring tool could be turned to any angle and set to work either horizontally forwards or sideways or vertically or at any intermediate inclination, by means of the several adjustments provided in the frame of the machine, so as to suit the best position and direction for inserting the hole, in order to obtain the greatest amount of shaken rock at one blast. A model of the frame was exhibited, showing the arrangement for allowing of turning the tool to work in any desired direction.

Mr. W. E. Newton enquired whether the machine could not be arranged for working two boring tools so as to bore two holes

at a time instead of only one. As the rate of excavating the tunnel at present by the machine was apparently hardly greater than by hand work, he suggested that the tunnel might be driven even faster by hand labour by employing a few more men, unless the machine could be arranged to bore two or more holes at a time.

Mr. J. ANDREWS replied that the machine could readily be arranged to work two or more boring tools at a time, and would have been employed in that manner had the tunnel been large enough to allow of working more than a single tool conveniently.

Sir JOHN GRAY, M.P., chairman of the Dublin Water Works, remarked that it must be borne in mind that the Roundwood Tunnel, in which the machine was now working, was so very small that in working by hand labour there was only room for boring one hole at a time, for which two men were required, one to hold the boring tool and the other to strike it with the hammer. In the case of any given hole the machine bored much more rapidly than could be done by hand, as was shown by the fact that in regular working the machine bored holes of 20 inches depth in 20 minutes each, which took 2 hours at least by hand labour. The machine was at present indeed only in an experimental condition, having been tried two or three times previously in different frames, the great object throughout having been not so much to save expense as to economise time; for the materials to be bored through in the formation of the tunnel had proved so much harder and more difficult of removal than had been expected, that it was found the tunnel could not be completed by hand labour within the time stipulated, and the machine had therefore been tried with the view of expediting the work. The first machine was tried for the purpose about twelve months ago, but did not prove sufficiently effective; and the second machine, though containing some improvements which made it a little more effective, still did not answer: the machine now in use, the third that had been tried, was the first which had performed any satisfactory work, and it certainly did bore in a narrow tunnel

much more rapidly than could be done by hand labour. If there were a larger space to work in, so that two or three of the boring tools could be put to work by the machine at the same time, the excavation would of course be proceeded with much more rapidly; and owing to the inconvenience of the present frame of the machine in the confined space of the tunnel, there was not sufficient facility for turning the boring tool to work at the different angles at which it was desirable that it should be employed in order to derive the full benefit from the use of the machine and reduce the amount of hand work in boring the holes. At present the machine was practically only able to work within a certain range of angle, so that only a comparatively small portion of the work of driving the tunnel was really done by the machine, and the rest had still to be done by hand labour. The practical result therefore up to the present time had not been so satisfactory even in regard to time as could have been wished, the machine not having produced a much more rapid rate of progress in driving the tunnel, notwithstanding the very great increase of rapidity in boring each individual hole by the machine.

Mr. C. Cochrane observed that, from the information which had been given respecting the practical working of the machine in the Roundwood Tunnel and the actual rate of progress of the work, it would appear that a very large proportion of the whole time must be absorbed in the mere adjustment of the machine between the boring of each successive hole, and also in executing the large proportion of corner work which had to be done by hand labour; for it was impossible otherwise to understand how there could be so little economy of time effected by using the machine, considering the very great increase of rapidity in boring the holes by the machine as compared with hand labour. He suggested that there might also be a good deal more delay in removing the machine before firing the charges than had been mentioned; because, although the machine ran upon a tramroad on which it could be drawn back quickly, there was the flexible air tube in the way, which would have to be removed first to avoid obstructing the passage of the machine.

Mr. Neville, engineer to the corporation of Dublin, said there was no doubt the greatest delay arose from the inconvenience and loss of time in moving the present frame of the machine in the small tunnel; a new frame was now being made for the purpose, with the modifications that had been found desirable for adapting it better to the circumstances of the situation, and when that was completed it was expected the progress of the work would be much more rapid.

The President remarked that it was evident the machine had not yet been long enough at work to allow of its full advantages being realised; but it was certainly one of great ingenuity, and from the particulars that had been given respecting its performance under the disadvantageous circumstances in which it had at present been employed there seemed no doubt that it would ultimately prove a valuable machine for rock boring.

He moved a vote of thanks to Mr. Low for his paper, which was passed.

The following paper, by Mr. Parke Neville, Engineer to the corporation of Dublin, communicated through the President, was then read:—

ON THE NEW DUBLIN CORPORATION WATER WORKS FOR THE SUPPLY OF WATER FROM THE RIVER VARTRY.

By Mr. PARKE NEVILLE, of Dublin.

The supply of Water to the city of Dublin was for several centuries obtained entirely from the River Dodder, Fig. 2, Plate 61, across which a weir had been constructed near Templeogue, at about 5 miles distance from Dublin, whence the water was and is still conveyed into Dublin by an open conduit called the "city water-course." In 1775 the water supplied from this source was found so bad and insufficient that the corporation arranged for obtaining what was then considered an ample supply of water from the Grand Canal; and in 1806, the quantity having again become insufficient, a better supply was procured from the Grand Canal and also from the Royal Canal, which was measured by overfalls of a certain length. This last arrangement was made to extend over a term of sixty years, and under it Dublin has been supplied up to the present date.

The Royal Canal supplies water to the north side of the city, and the Grand Canal and city water-course to the south side; the water for the former being received into the city basin at Blessington Street, and for the latter into the James Street and Portobello basins. The level of the water in the north basin is 78 feet, and in the south basin 76 feet, above ordnance datum, which is the level of low water of a 12 foot tide. The surface levels of the lowest parts of the city along the quays range from 20 to 28 feet above this datum, and the head of water in those parts is therefore only about 50 feet, while over the average of the city it is not more than 25 feet, and some parts are at too high a level to be supplied at all.

The water obtained from the Dodder is of a soft quality, and would be very good for domestic use, were it not for the pollutions received from paper and other mills, which have been allowed to be erected from time to time along the course of the river. The water of the canals is very hard, having a hardness of 15 to 16 degrees by Dr. Clark's test, a hardness of 1 degree being that due to 1 grain of chalk dissolved in 1 gallon of distilled water; and the canal water is also liable to great pollution.

For many years the want of a really good supply of soft water and at high pressure for the city and the suburban districts was strongly felt, and various plans have been proposed for obtaining a new or improved supply. In 1857 it was proposed to obtain a supply from the canals at a higher level, where their water was more pure; and it was afterwards proposed to obtain water from the Liffey at about 20 miles above Dublin. But finally in 1860 the whole question of the water supply to Dublin was referred to a royal commissioner, Mr. Hawkshaw, who recommended obtaining a supply of water from the River Vartry. An Act was passed in 1861 for the purpose of carrying this into effect, and the work was commenced in November 1862, the amount of the contract for the whole being £274,000.

In Fig. 1, Plate 60, is shown a plan of the drainage area from which the supply of water is obtained; and Fig. 2, Plate 61, is a general plan of the whole course of the water works from the River Vartry to Dublin. Fig. 3, Plate 62, is a longitudinal section along the line of the works.

The River Vartry rises at the southern base of the Great Sugarloaf Mountain in the county of Wicklow, Figs. 1 and 2, and flowing in a southerly direction through a very thinly populated country reaches the Devil's Glen at a distance of about 10 miles from its source. After passing over the fall it continues through the glen to the Broad Lough, from which it flows into the sea at Wicklow. The water of the Vartry is collected entirely from a clay-slate district, and is peculiarly soft and pure, and during the greater part of the year quite free from all colour; it is almost identical

in analysis with the Loch Katrine water which now supplies Glasgow.

Rain gauges have been set up in different positions and at different elevations within the drainage area of the catchwater basin, Fig. 1, which have been accurately observed for more than four years; and they have registered the following as the average annual rainfall over the whole area:—

In 1861	....	60·87 inches.
1862	....	60·48 ,,
1863	....	44·85 ,,
1864	....	48·39 ,,

This is a much larger rainfall than was originally calculated to be yielded by the district, and leaves no doubt as to the sufficiency of the supply; and the whole of the water from the catchment is available for the waterworks purposes, as all mill rights &c. along the course of the river have been bought up, and no compensation water has to be given off.

The place selected for the formation of the storage reservoir is at Roundwood, Fig. 1, about $7\frac{1}{2}$ miles below the source of the river; and at the point A, where the great embankment for the reservoir has been constructed, the bed of the river is 632 feet above ordnance datum, or 520 feet above the highest part of Dublin. The drainage area above this point is 13,992 acres or 22 square miles, and the area of the reservoir will be 409 acres. When full, the level of the water will be 692 feet above the datum; and the reservoir will hold about 2400 million gallons of water, or 200 days' supply for the city and suburban districts, taking the daily quantity required at 12 million gallons; but this is much in excess of what it is expected will actually be required for many years, as the present population to be supplied is only about 340,000. The quantity calculated for would supply a population of 400,000 with 25 gallons per head per day, and leave a surplus of 2 million gallons per day for manufacturing and other purposes.

The main embankment of the Roundwood reservoir is 66 feet high in the deepest part, and the greatest depth of water in the reservoir is 60 feet. The embankment is 2000 feet long on the top, and has a public road 24 feet wide carried over it; the entire breadth

of the bank at the top is 28 feet, and at the base in the deepest part 380 feet. The outer slope is $2\frac{1}{2}$ to 1 and the inner 3 to 1; and the total quantity of earthwork in the embankment is 320,000 cubic yards. The puddle wall is 6 feet wide at top, and about 18 feet wide at bottom on the level of the surface of the old river bank; and throughout its entire length the puddle wall is carried down to the solid rock. The by-wash or waste weir is 300 feet wide, and discharges into the old river course, as shown at B, Fig. 1.

A tunnel for the outlet from the reservoir is formed under the eastern end of the embankment, by excavating an open cutting into the rock, and then arching it over with a semicircular arch of ashlar stone 4 feet thick; it is 14 feet high by 14 feet wide in the broadest part. Near the centre of the tunnel is a brick plugging 20 feet thick, carefully toothed into wedge-shaped recesses in the solid rock. Through this plugging are laid two cast iron pipes of 48 and 33 inches diameter; the larger of which is intended chiefly as a sluice for lowering the water level in the reservoir quickly, and is to be continued into the tail of the by-wash, near where the latter joins the old river course. The 33 inch pipe is for conveying the water into the circular distributing basin, from which it passes by conduits to the filter beds, and thence into the pure water tanks. In the valve chamber at the outer end of the embankment tunnel a very complete set of stop-valves is placed for enabling both the 48 and 33 inch pipes to be worked as may be required. At the inner end of the embankment tunnel is built a water tower, into the bottom of which the 33 inch pipe is carried; and in the sides of the tower are inlet openings, with valves fixed on the inside, for enabling the water to be drawn from the reservoir at different levels, in order that it may be drawn off in the best state for use.

The filter beds and pure water tanks cover about 6 acres. There are seven filter beds, each 205 feet long by 110 feet wide; and any six of these working at the same time will be sufficient to filter the required quantity of water, so that one can always be spared for the purpose of cleansing and washing the sand and for repairs. The filtering material employed will be sand, gravel, and

broken stone. The two pure water tanks which receive the water from the filters hold 2,730,000 gallons of water each, and are placed so that four of the filters are on one side of them and three on the other, the remaining space on the latter side being occupied by a sand-cleansing machine and store for the sand. From these tanks the water will be carried for a distance of about 700 yards in a cast iron pipe, 42 inches diameter, laid with a fall of 6 feet per mile, until it reaches the tunnel, into which it is carried for a length of 120 yards so as to get to the solid rock.

This tunnel is 4367 yards long or nearly $2\frac{1}{2}$ miles, the entire length being through very hard Cambrian rock full of quartz veins. Twenty-one shafts have been sunk along the course of the tunnel, as shown in Fig. 1, from which the miners work right and left; and up to the present date the headings from five of the shafts have met, and 3160 yards or $1\frac{3}{4}$ miles have now been tunnelled. The tunnel is 6 feet high and 5 feet wide, and has a fall of 4 feet per mile throughout. This work has turned out much more difficult and tedious than was anticipated, chiefly owing to the hardness of the rock, and the great quantity of water met with in the shafts and headings, which requires very large pumping power; and it is calculated that the tunnel cannot now be completed before the latter end of next year.

At the lower or Dublin end of the tunnel there will be a relieving tank and measuring weir, where the water passed down for the supply of the city will be gauged daily. From this tank, in which the surface of the water will be 606 feet above the ordnance datum, a 33 inch main conveys the water to the distributing reservoirs at Stillorgan, having a self-acting stop-valve at its junction with the tank, to prevent flooding in the event of a pipe bursting.

The average falling gradient of the main is 20 feet per mile, and it passes the village of Newtown Mount Kennedy, near which there is another self-acting stop-valve at the point C in Figs. 2 and 3; it then passes along the coach road through the Glen of the Downs to the Kilmurray relief tank, which is about 7 miles from the lower end of the tunnel. This tank is circular, excavated out of a gravel

hill, and lined with puddle covered with pitching. The end of the main delivering into the tank has a 33 inch double-acting stop-valve, and there is a self-acting valve on the mouth of the main leaving the tank. The surface level of the water in this tank is 473 feet above ordnance datum.

The main is then brought down again to the road, and continued 3 miles to the Kilcrony relief tank, situated on the top of the southern bank of the Dargle, and commanding a remarkably fine and extensive view. Owing to the loose character of the quartz rock in which this tank is excavated, it has to be lined with puddle. The water level is 414 feet above the datum, and the tank is provided with inlet and outlet valves similar to those at the preceding tank.

The main is then carried down under the Dargle River, and afterwards under the Cookstown River to the Rathmichael relief tank at $3\frac{1}{2}$ miles distance, which is excavated in the rock and happens to be situated exactly on the junction of the granite with the clay-slate, so that one side of the tank is in granite and the other in slate. This is a square tank, and puddled; and the level of the water in it is 341 feet above the datum. Here also there will be a double-acting stop-valve and a self-acting valve, as described for the other tanks.

The main is then continued for nearly 4 miles, partly along the Wicklow Railway, having a self-acting valve and stop-valve inserted in this length at D, Figs. 2 and 3; and it terminates at the two distributing reservoirs at Stillorgan, making a total distance of about $16\frac{3}{4}$ miles from the lower end of the tunnel.

The water area of the Stillorgan reservoirs is 18 acres, and their average depth about 20 feet, so that the two will contain about 90 million gallons of water. The surface level of the water in the upper reservoir is 274 feet, and in the lower 271 feet above the datum; and the latter is therefore the working pressure for the supply of Dublin, the distance being $4\frac{3}{4}$ miles from the city boundary, making the total distance from the Roundwood reservoir to Dublin about $24\frac{1}{2}$ miles. The 33 inch Vartry main is laid into each reservoir, and the stop-valves are so placed that either

reservoir can be worked at pleasure; the two reservoirs are also connected together by a pipe laid through the dividing embankment.

At the lower reservoir is constructed the valve-house and screen-chamber, into which mains from each reservoir are laid, together with one in direct continuation from the Vartry main; and by the system of valves placed in this chamber the water can be drawn from either of the reservoirs, or direct from the Vartry main. In the latter case it is not exposed in the reservoirs at all, which in warm weather it is calculated will be a great advantage, as the water will thereby be delivered cold and pure. At the same time there is the security of having always about 10 days' supply of water in the reservoirs in case of any accident to the main pipe, thus allowing ample time for any repairs.

The screen-chamber will contain a set of copper wire screens, through which the water will be strained before entering the delivery mains, so as to remove the possibility of any small substance being carried into the mains. These screens will be cleansed periodically by a hose and jet, and the arrangements of valves are such as to allow of this being done at any time without interfering with the regularity of the supply.

A double line of 27 inch mains are laid out of the screen-chamber, with self-acting valves, extending $4\frac{3}{4}$ miles to the city boundary. The double line has been laid with the view of preventing the possibility of any stoppage in the supply by the bursting of a main or the necessity for any occasional repair; and connections are made between the two mains at three points, with groups of stop-valves to afford the means of turning the water from one main into the other as occasion may require. Air valves have been placed on all summits, and scouring valves in all hollows.

The total cost of the entire works when completed, including £60,000 spent in the extension and improvement of the pipes within the city, will be less than 30*s.* per head of the population supplied, which is a very low amount as compared with the cost at other places.

Mr. Neville mentioned that the paper just read had been prepared simply as a general description of the works, to serve as a guide for the Members in connection with the excursion to be made on the following day for visiting the works, and not with a view of entering fully into the details of the works.

Mr. J. Murphy enquired whether any attempt had been made to procure water in Dublin or the neighbourhood by boring, before the present plan of supply from Roundwood was decided upon. He did not think it was sufficient to infer merely from geological indications the supply of water that would be obtained from wells, in the absence of an actual trial by boring; because boring frequently brought to light facts which had not been anticipated. In the boring for coal at Middlesbrough, which he had previously mentioned, instead of the coal that was expected to be found, a bed of pure rock salt 100 feet thick was met with, the existence of which had not been suspected from any previous indications.

The President observed that one objection to obtaining the water supply by boring would be the want of gravitation in that case for the distribution of the supply. The great advantage of the scheme now being carried out would be that the gravitation would save all pumping and boring; it entailed of course the expense of damming up the water in the first instance and conveying it into the city, but all heavy expense afterwards for constant pumping was then avoided. This had been the view taken of the question at Glasgow, where the water supply had formerly been by pumping from the Clyde; but that plan had now been abandoned and the water was brought in by gravitation from Loch Katrine, as described in the paper read at the meeting of the Institution in Glasgow last year. In the new Dublin Water Works, he thought there might be some difficulty in filtering the water, owing to the quantity of sand which would perhaps be found to be brought down by the water from the extensive drainage area from which the water was collected. When the water for Glasgow had been drawn from the Clyde it contained so much sand that there had been great trouble in filtering it, owing to the sand getting into the filter beds and stopping their action, in consequence of which they

required to be cleaned often. Perhaps however the Vartry water might not have so much sand in it as the Clyde water.

Sir John Gray, M.P., chairman of the Dublin Water Works, said that before the gravitation plan was decided upon a proposal had been made to try the boring process for getting water; but they had ultimately come to the conclusion that a great many wells would have to be sunk and a large number of pumping engines erected in order to give the required supply, and that that mode would be much more costly on the whole and not nearly so effectual as the gravitation plan now being carried out. Moreover water taken from the strata underneath Dublin would be largely impregnated with lime; for near his own residence only two miles from Dublin and on nearly the same geological formation the hardness of the well water was in one case found to be as much as 91° on Dr. Clark's scale (in which a hardness of 1° is that due to one grain of chalk dissolved in one gallon of distilled water, the hardness being the property of destroying soap). The well water in Dublin was not so hard as this, but it varied from 20° of hardness upwards, and was therefore considerably harder than the canal water. By carrying out the gravitation plan the supply would be self-acting, with a high pressure for fire service and for general house service, and a better quality of water would be obtained at a much cheaper rate than would be possible in any other way.

Mr. Neville remarked that another objection to the pumping plan was that the geological formation on which Dublin stood was not such as to warrant by any means the anticipation of a sufficient water supply. It was quite a different case from that of Cardiff, which had been alluded to in the previous discussion, where it had been stated that a supply of good water had been obtained from the old red sandstone by boring.

Mr. W. E. Newton enquired upon what terms it was proposed to supply the water in Dublin, whether by meter or by a charge upon the rental of the houses.

Sir John Gray replied that both modes of charging for the water supply would be adopted. The house supply would be at a

poundage rate of 1*s.* in the pound on the valuation of the property; this would be a compulsory rate, the inhabitants being obliged to pay this rate for the water, whilst on the other hand the corporation was compelled to supply the water. The amount of the rate however was not so high as the same nominal rate in England, where a public assessment was usually made upon the rental of the property; for in Dublin a public valuation was made of all property, which was determined by law to be on an average 25 per cent. below the rental of the property; so that the rate of 1*s.* in the pound was equivalent to only 9*d.* in the pound in England, and in fact rather less, owing to the lower proportionate rentals of property in Dublin as compared with most large towns in England. The other mode of supply, by meter, was intended principally for manufacturing purposes, and an ordinary meter rent would be charged for keeping the meters in repair, and a fair rate for the water supplied. The charge for the water was not fixed, but the rate would be matter of agreement in each case.

Previous to the commencement of the works now in progress the old system of rating in Dublin had been by a sliding scale, which pressed very unequally on the poorer classes. It began at 5*s.* per annum for a certain class of perhaps very small houses, and rose to 10*s.* and 15*s.* for other classes; and 30*s.* per annum had been the highest rate that could be charged upon any class of house. There was also another very defective arrangement under the old system, by which a bath, a water-closet, and a stable were each charged for separately in addition; in consequence of which it was calculated that a person living in a very moderate sized house might have to pay for water as much as 2*s.* 3*d.* in the pound on his valuation, whilst another person living in a larger house but without those extras might be paying no more than from 3*d.* to 4*d.* in the pound for water supply. It had therefore been concluded that the old system of charging was very unjust, and that it would be better to have the equal method of rating at 1*s.* in the pound on the valuation of all property; and it had also been satisfactorily ascertained beforehand that this amount of rate would not only never have to be exceeded, but that it would do

more than pay for all the expenses of the works, leaving a large fund in the hands of the corporation for the public benefit, and allowing ultimately of a reduction in the rate itself.

The PRESIDENT thought the rate of 1*s.* in the pound in Dublin, which was equivalent to only 9*d.* in the pound in England, was a very moderate amount. In Glasgow the rate had been at first as much as 1*s.* 2*d.* in the pound on the rental, but it had now been reduced to 1*s.*, which was found ample, leaving a large amount of profit, and he thought it very likely that the rate would be still further reduced before long.

With regard to the quantity of water proposed to be supplied to Dublin, 12 million gallons per day to a population of 340,000 appeared small in comparison with that in Glasgow, where the population was not one half more than in Dublin but the quantity of water supplied was 23 million gallons per day. No doubt there was great extravagance and waste of water in Glasgow to account for so large a consumption per day; and it remained to be seen whether the population in Dublin would be so much more careful of the water as to find the smaller supply sufficient.

Sir JOHN GRAY said the water supply to Glasgow was certainly extravagantly large, and not only was more water used there than was at all necessary but there was also a very large waste indeed. He understood that means were being devised for reducing the waste, and that it had already been reduced as much as 8 or 10 million gallons per day by a better mode of inspection. The possibility was contemplated of a large waste occurring in Dublin, unless provision were made to prevent it; for at present it had been ascertained that under the existing system of supply there was more water wasted in Dublin than was used. It had therefore been determined to prevent such excessive waste under the new supply, and although the new works would not be completed for more than a year, the water arrangements and fittings of every house were already being inspected, and it was intended to have a system of house tap service of the most perfect kind that could be obtained, in order to prevent any needless waste, and in that way to render the water supply quite sufficient for the

F 2

requirements of the population, though not so large per head as that of Glasgow. In Manchester, which was considered to be very well supplied with water, the daily supply per head was under 21 gallons, and he understood that quantity was found amply sufficient ; and the supply contemplated for Dublin of 12 million gallons per day would therefore be much larger than the Manchester supply, as it would be equivalent to as much as 35 gallons per head per day to the present population of 340,000.

Mr. Neville remarked that the quantity of water required for manufacturing purposes in Glasgow was from ten to twenty times as great as that employed for the same purposes in Dublin, which might partly account for the much larger consumption in Glasgow.

The President believed the great waste of water in Glasgow was in connection with the house supply, though he could not understand how any one could manage to waste more than 25 gallons per head per day, and he considered a much smaller quantity would be amply sufficient for all reasonable requirements.

Mr. J. Murphy thought that with such an abundant supply of water as would be obtained from the extensive watershed at Roundwood it would be a great mistake to limit the quantity of water to be used in such a city as Dublin, for he considered that nothing was more conducive to the salutary condition of a town than a plentiful supply of water. Moreover that which was spoken of as waste of water ought not to be regarded as altogether wasted, for it passed into the sewers and cleansed them, by removing impurities which could not be removed by other means ; and he believed this mode of cleansing the sewers was found preferable to flushing them at intervals, which he understood had been attended with injurious effects in many cases in consequence of the violent current of water washing away the mortar from between the bricks of the sewers and thereby causing them to fall in.

The President suggested that if the flushing of the sewers were placed under the control of the corporation it might be done at the most suitable periods for efficiently cleansing the sewers, which would be better than allowing an indiscriminate waste of water, when one part of the sewers might perhaps be

clean where the water was much wasted, and another part foul where there was less waste.

Sir JOHN GRAY explained that the whole management of the water, sewerage, and streets of Dublin was now in the hands of the corporation ; and great advantage was expected to result from the unity of action that would thereby be obtained. With regard to waste of water he believed it was a mistake to suppose that any benefit as to flushing of sewers arose from a continual waste running into the sewers ; for it had been found by experiment that a continual dribble of water which might be very wasteful to the water supply had very little beneficial effect in cleansing the sewers ; and he believed that a good system of periodical flushing would do far more to remove refuse matter and carry off putrescent gases at one tenth the expenditure of water. There would be no difficulty in arranging for an extensive and frequent flushing of the sewers in Dublin, as there was a plentiful supply of water to be obtained for that purpose from the upper part of the river Dodder, without requiring any of the water from Roundwood to be expended in that way. But any waste of water from the taps in a house tended to cause damp and ill-health, while it would produce no beneficial effect whatever in the sewers. The merest thread of water, barely visible but constantly flowing under high pressure, was sufficient to produce a waste of more water than the entire household would consume ; and such seemingly small waste from each house throughout the city would cause more water to be wasted than was actually made use of out of the whole water supply. A prime requisite therefore in town supply was sound and durable taps.

Mr. J. MURPHY enquired whether the water supply was intended to be constant or intermittent, as the value of a constant supply was far greater than that of an intermittent supply, where the quantity supplied per day was comparatively small.

With regard to the supply of water by meter for manufacturing purposes, it had been mentioned that the charge for the water in that case was to be determined by an agreement between the water company and the consumer ; and he thought that difficulties

might frequently arise in coming to an agreement which would be considered satisfactory on both sides. At his own works at Newport in Monmouthshire the cost of water according to the rate charged by meter would have amounted to as much as £60 to £70 a year for a supply of water to the smith's forge and engine of 40 horse power; but he had then bored for water, and succeeded in obtaining a supply by that means, after which the company had offered to supply water to the works for £10 per annum. The mode of rating was also a matter of dispute in Newport, and it was therefore contemplated by the corporation of that town to make a purchase of the water works, and establish a more satisfactory system of supplying manufacturing premises.

Sir John Gray remarked that as the water supply of Dublin was now entirely in the hands of the corporation the inhabitants who elected the corporation were really the controlling power, and it was not anticipated therefore that there would be any difficulty in coming to a satisfactory arrangement for the charge for water supplied by meter for manufacturing purposes. No decision had yet been arrived at upon the subject, but it was the intention of the corporation to ascertain the arrangements existing in several of the principal manufacturing towns in England and Scotland, and by taking an average of their charges to arrive at a just price for the water supplied to the manufacturers in Dublin. Whatever the amount of the profit derived from this source, it would go not to a private company but to the corporation, and would thus be shared in by all the inhabitants.

In reference to the nature of the new water supply to the city, it was intended to be constant, and would have the advantage of being also at high pressure. The water would be supplied by gravitation from the service reservoir at Stillorgan, about five miles distant from the city, and with a head pressure amounting to 250 feet above the lowest street level.

The President proposed a vote of thanks, which was passed, to Mr. Neville for his account of the Water Works, and to Sir John Gray for his kindness in giving the further information that had been asked for in connection with the subject.

The President proposed a vote of thanks, which was passed, to the Local Committee, and the Honorary Local Secretaries, Dr. Downing and Mr. G. Arthur Waller, for the excellent arrangements they had made for the meeting of the Institution in Dublin; and also to the Provost and authorities of the University of Dublin for their kindness in granting the use of the Examination Hall for the purpose of the meeting; and to the several Railway Companies for the special facilities they had so kindly afforded to the Members for attending the Meeting in Dublin and the Excursions in connection with the meeting.

The Meeting then terminated. In the afternoon the Members visited the various engineering establishments and other works which were opened to their inspection during the days of the meeting.

In the evening the Members and their friends dined together at the International Exhibition Building, in celebration of the meeting of the Institution in Dublin.

On Thursday, 3rd August, an Excursion was made by the Members from Dublin by special free train, granted by the Dublin and Wicklow Railway Company, to visit the works in progress of the Dublin Corporation Water Works at the Stillorgan and Roundwood Reservoirs, proceeding from Bray through the Glen of the Downs along a portion of the line of Pipes; and returning from the Roundwood Reservoir up the valley of the River Vartry, traversing the drainage area of the water supply, and passing by the Rocky Valley at the foot of the Sugarloaf Mountain. The Rock Boring Machine was seen at work in the Roundwood Tunnel; and the Members were handsomely entertained at the Roundwood Reservoir by Sir John Gray, M.P., the chairman of the Water Works Committee of the Corporation, and Mr. John Jameson, the deputy chairman.

On Friday, 4th August, an Excursion was made by the Members from Dublin by special free train, granted by the Great Southern and Western Railway Company, to visit the Derrylea Peat Works, near Portarlington, where the several processes of harrowing the peat bog, collecting and drying the peat mull, and compressing it in the peat presses into the circular discs were shown in operation by the managing director, Mr. Charles Hodgson, together with the employment of the compressed peat fuel for melting iron in the foundry. The Members were hospitably entertained by the Peat Company at the works.

On Saturday, 5th August, an Excursion was made by the Members from Dublin by free train, granted by the Dublin Wicklow and Wexford Railway Company, to visit the Connorree Copper and Sulphur Mines in the Vale of Avoca, under the guidance of the chairman, Dr. Waller, where the mining works and large adit were seen, and the process was shown of precipitation of copper in water upon iron. The Members were hospitably entertained at the works by the directors and officers of the Mining Company.

SAFETY VALVE. *Plate 63.*

Naylor's Safety Valve.

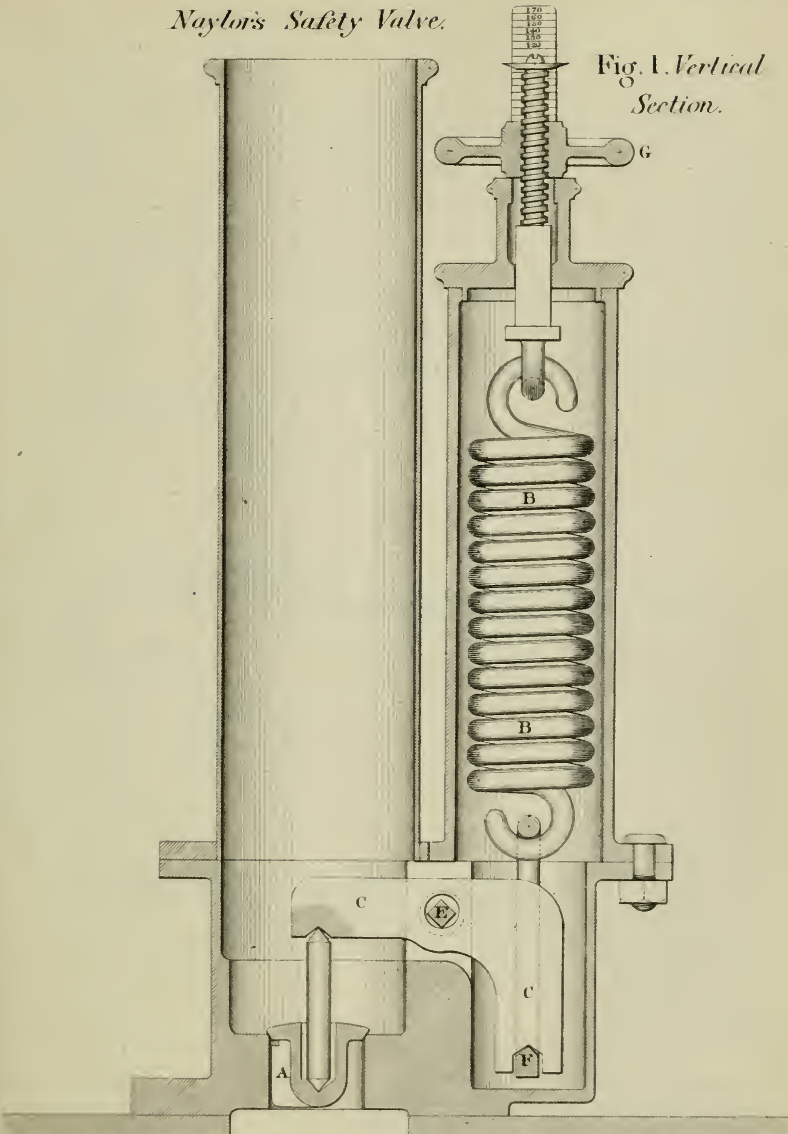


Fig. 1. *Vertical Section.*

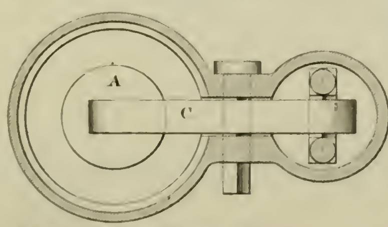


Fig. 2. *Sectional Plan.*

(Proceedings Inst. M.E. 1865. Page 220.) *Scale 1/4th.*

SAFETY VALVE.

Plate 64.

Fig. 3.

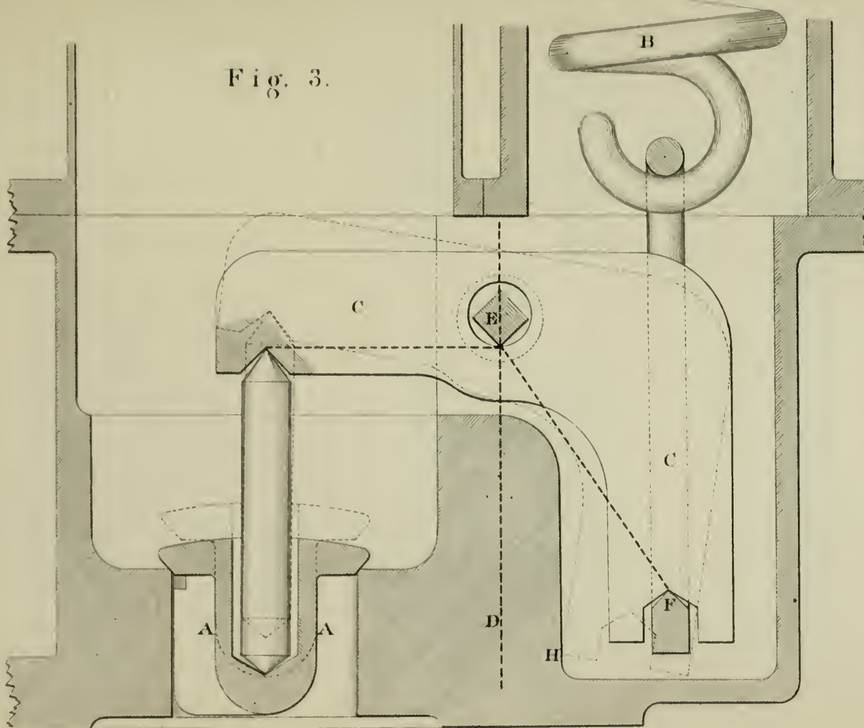
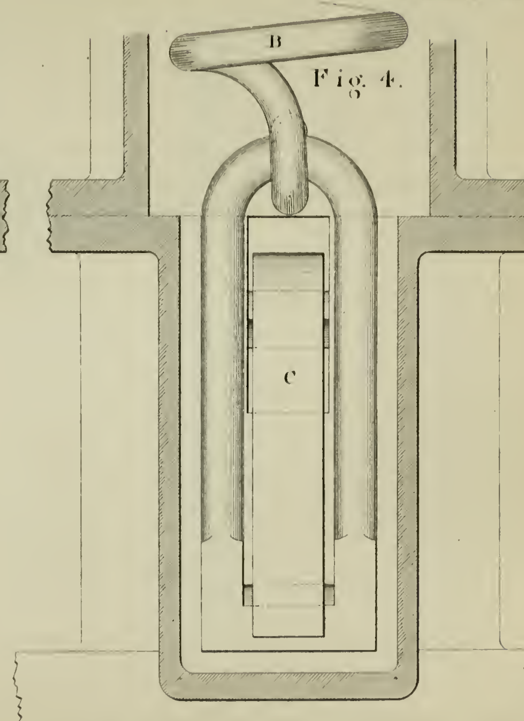


Fig. 4.



(Proceedings Inst. M.E. 1865. Page 220.)

Scale half full size.

SAFETY VALVE.

Safety Valve for marine boilers.

Fig. 5.

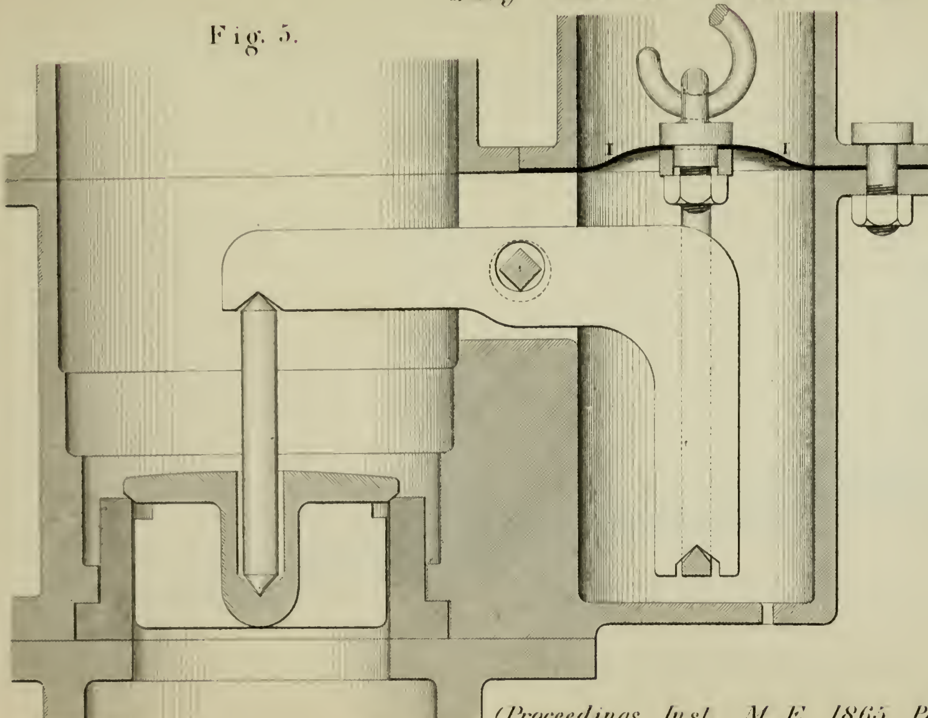
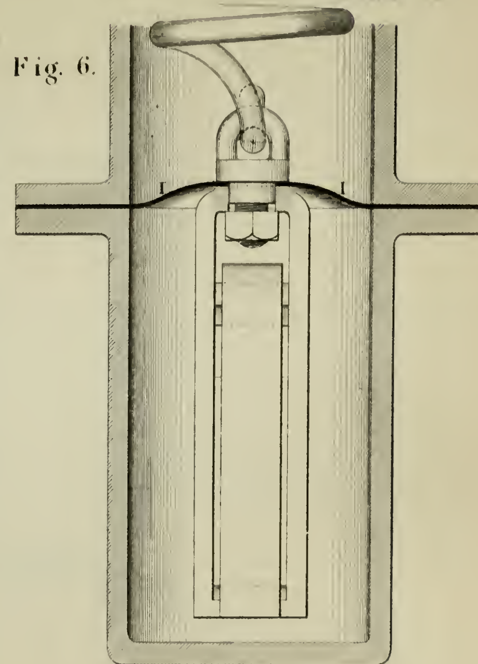


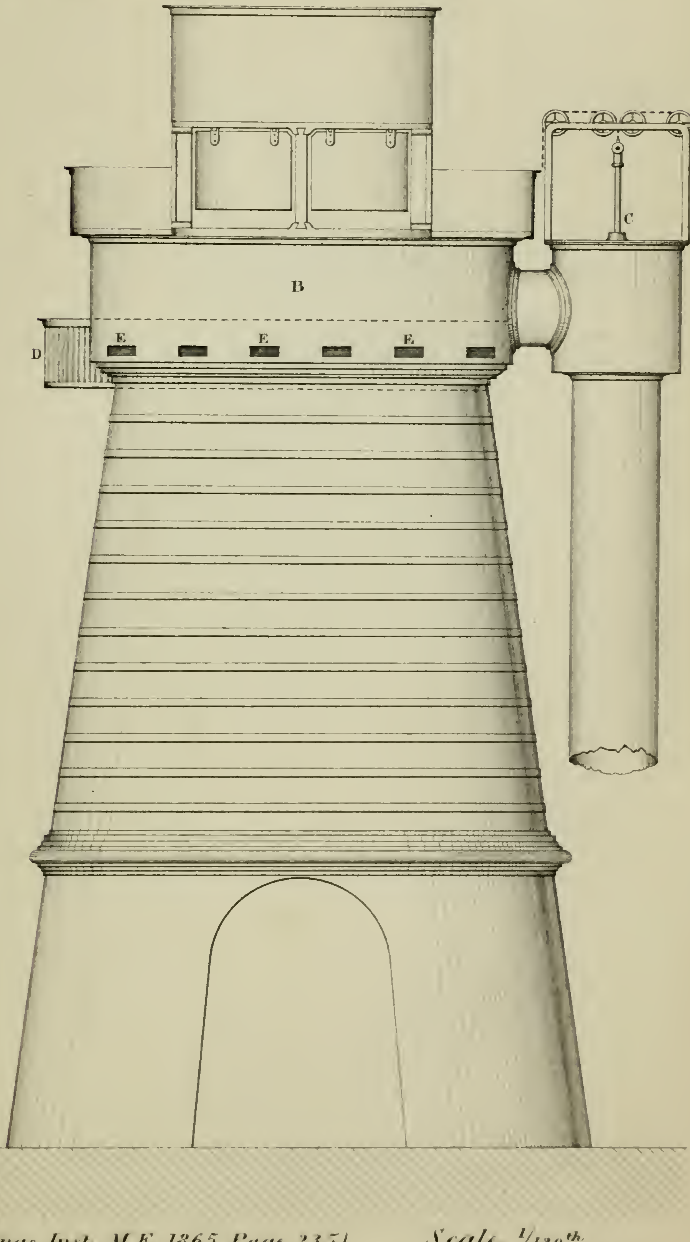
Fig. 6.



(Proceedings Inst. M. E. 1865. Page 220)

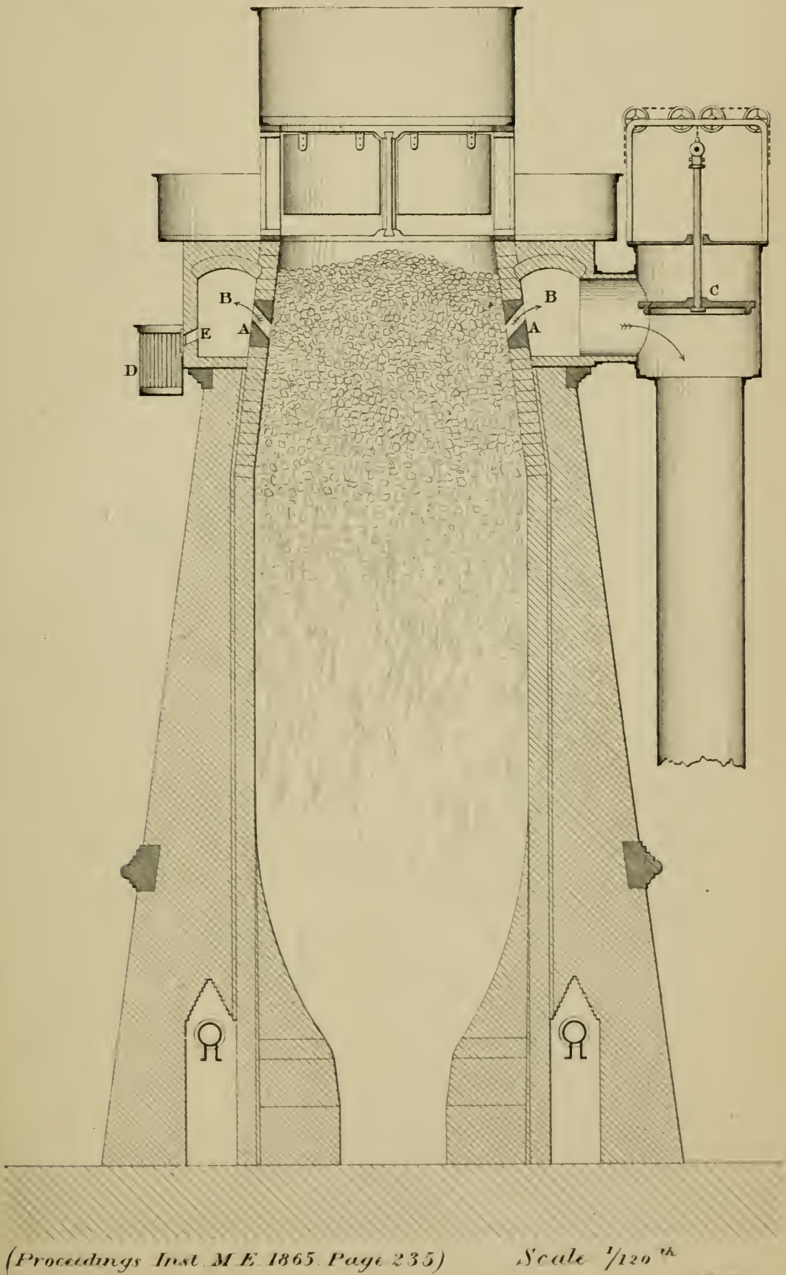
Scale 1/4 th

Fig. 1. *Elevation of Open-topped Blast Furnace at Rough Hay Iron Works, Darlaston.*

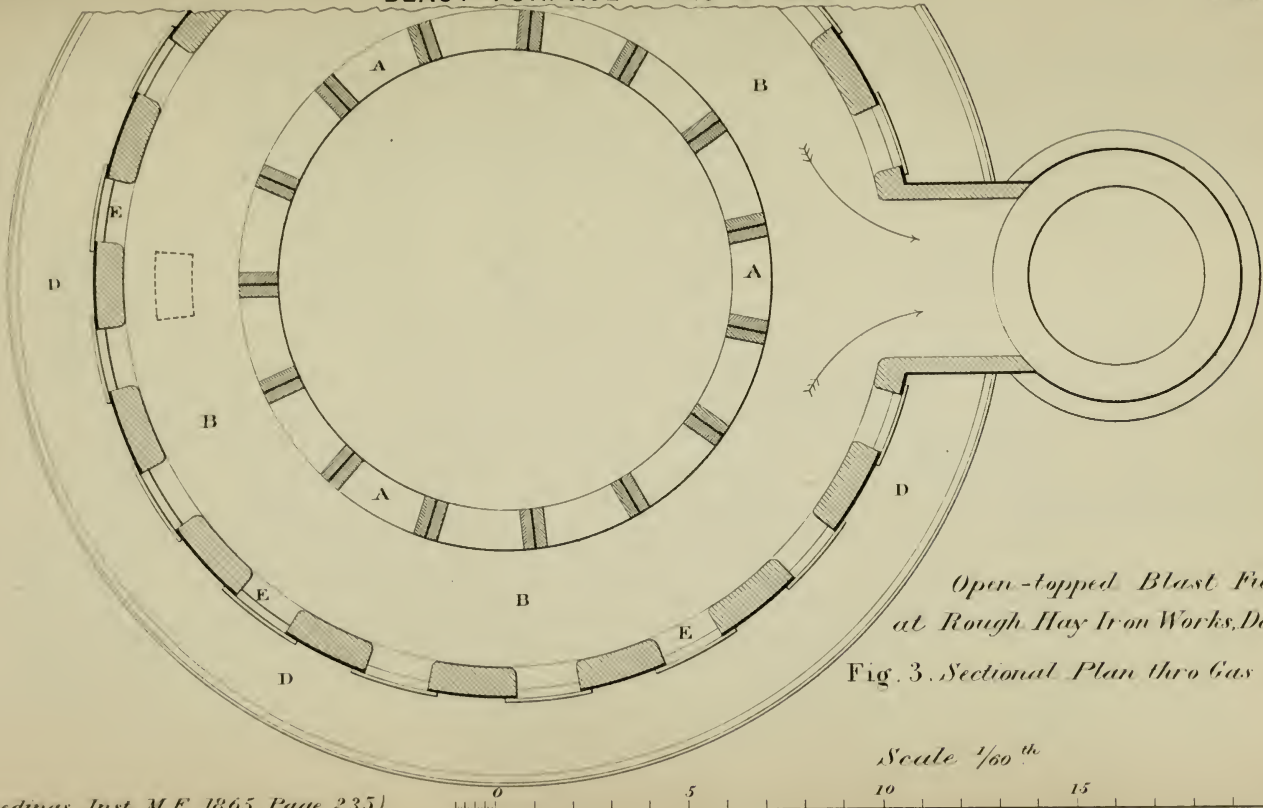


(Proceedings Inst. M. E. 1865. Page 235.) *Scale 1/120th*

Fig. 2. *Vertical Section of Open-topped Blast Furnace at Rough Hay Iron Works, Darlaston.*



(*Proceedings Inst. M. E. 1865. Page 235*) *Scale 1/120th*



Open-topped Blast Furnace
at Rough Hay Iron Works, Darlaston.

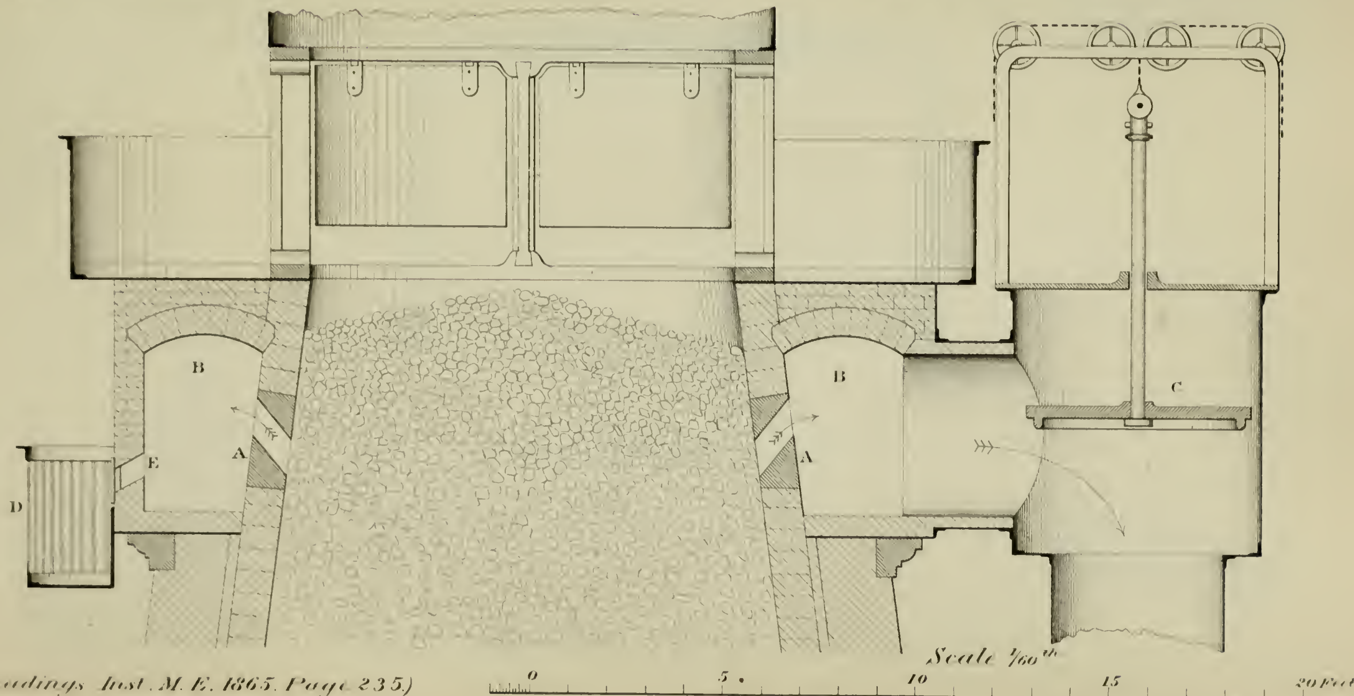
Fig. 3. Sectional Plan thro Gas Openings.

Scale 1/60th

BLAST-FURNACE WASTE GAS.

Plate 69.

Fig. 4. *Enlarged Section of Open Top of Blast Furnace at Rough Hay Iron Works, Darlaston.*



(Proceedings Inst. M. E. 1865. Page 235.)

BLAST - FURNACE WASTE GAS.

Open-topped Blast Furnace at Rough Hay Iron Works, Darlaston.
Detail of Castings for Gas Openings.

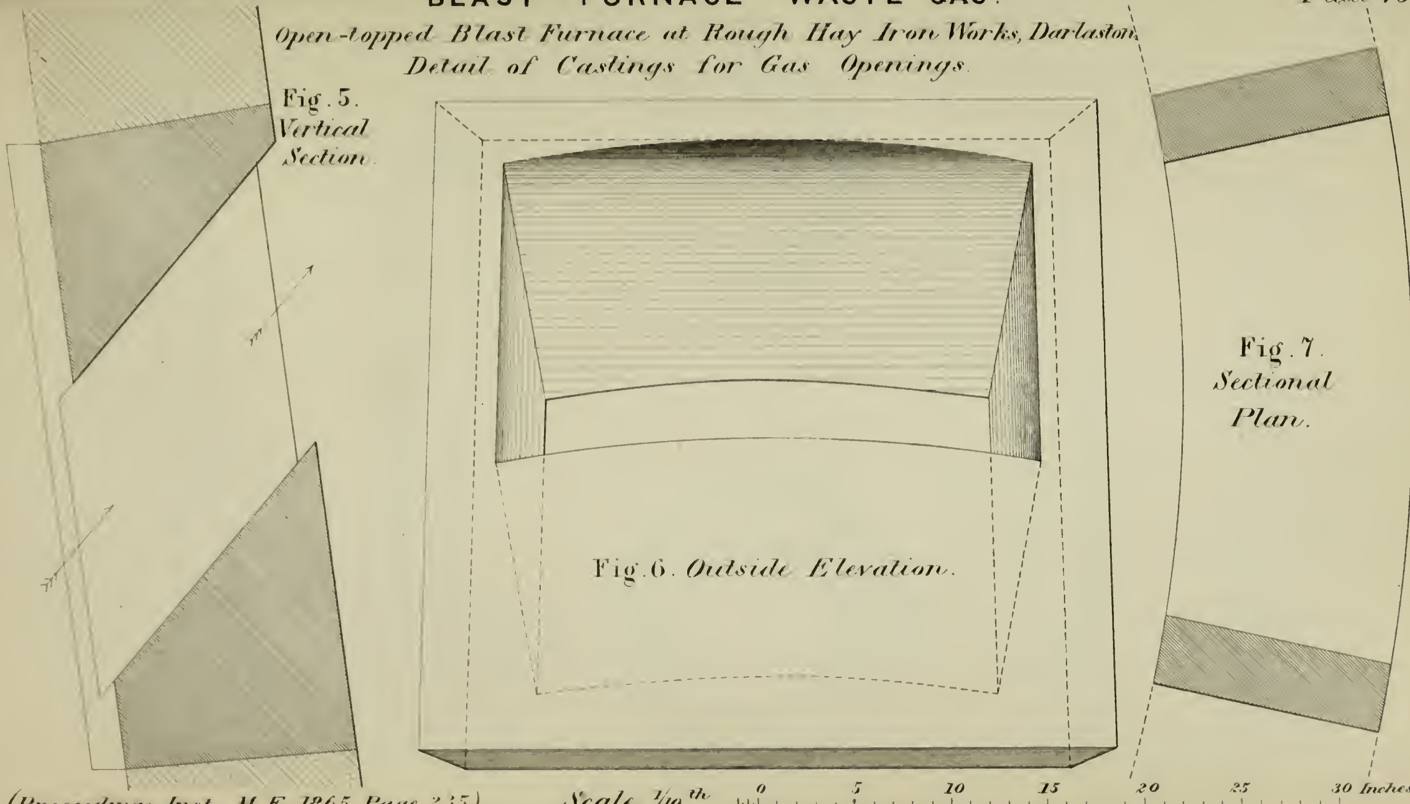


Fig. 1. *Longitudinal Section of Cast Iron Tuyere.*

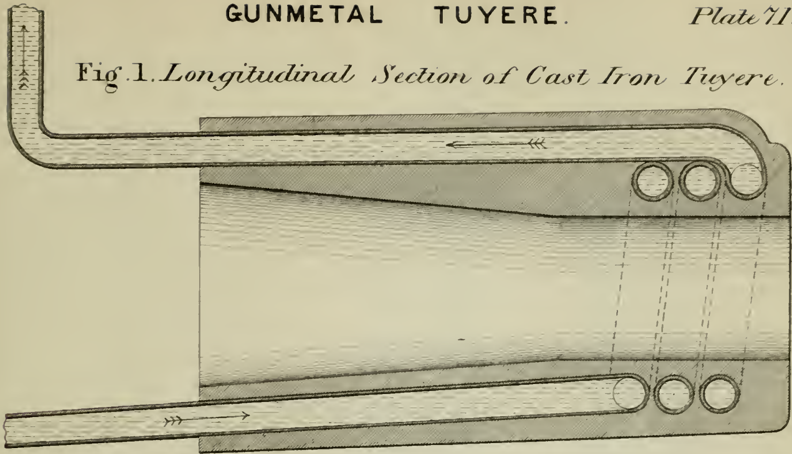


Fig. 3. *Back Elevation of Wrought Iron Tuyere.*

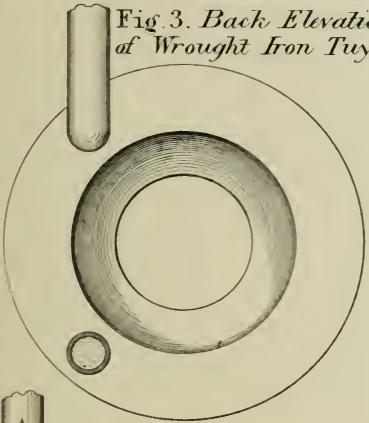


Fig. 2. *Transverse Section of Cast Iron Tuyere.*

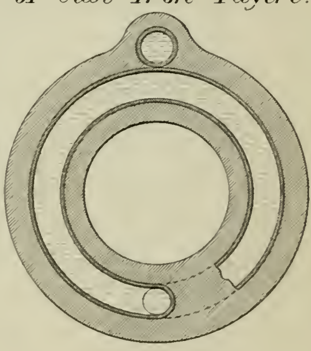
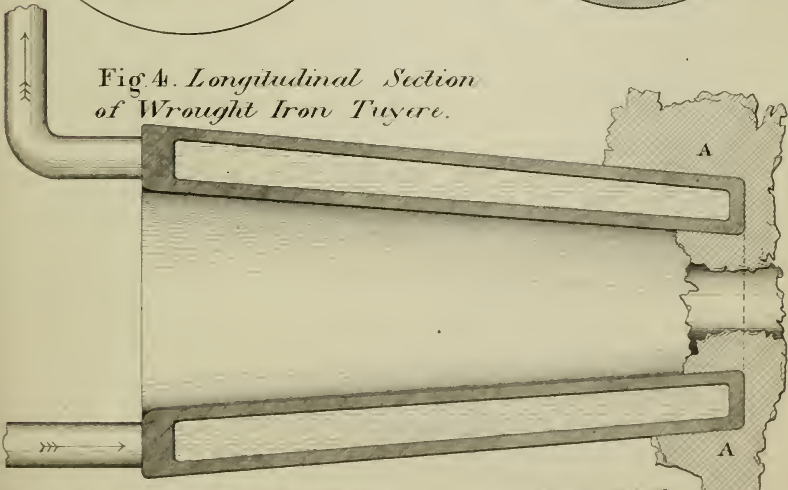


Fig. 4. *Longitudinal Section of Wrought Iron Tuyere.*



(Proceedings Inst. M.E. 1865. Page 256.) *Scale 1/6th.*

0 5 10 15 20 *Inches.*

GUNMETAL TUYERE.

Fig. 5. *Back Elevation.*

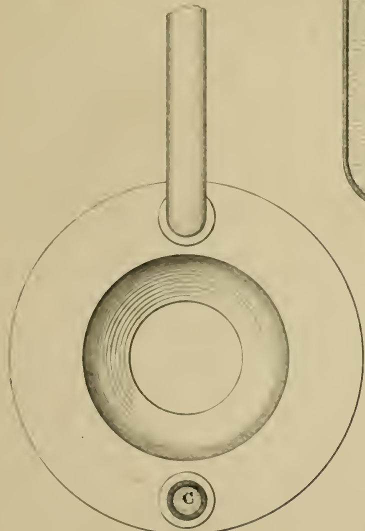
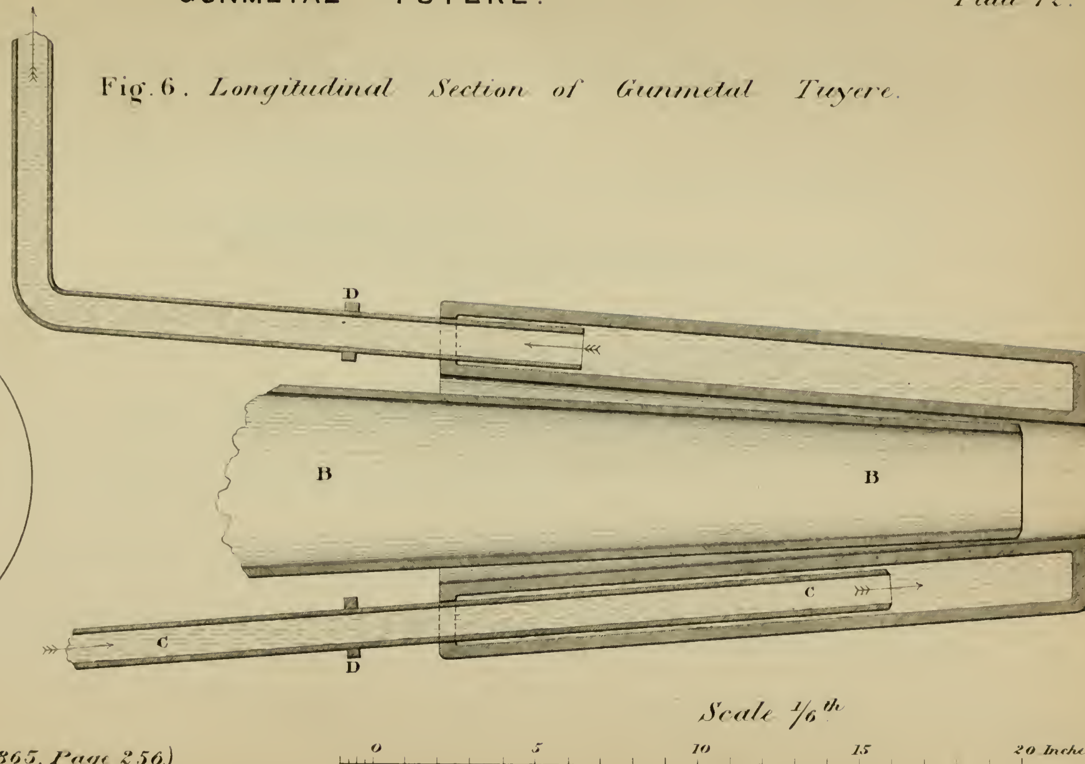


Fig. 6. *Longitudinal Section of Gunmetal Tuyere.*



GUNMETAL TUYERE.

Fig. 7. Longitudinal Section of improved Gunmetal Tuyere.

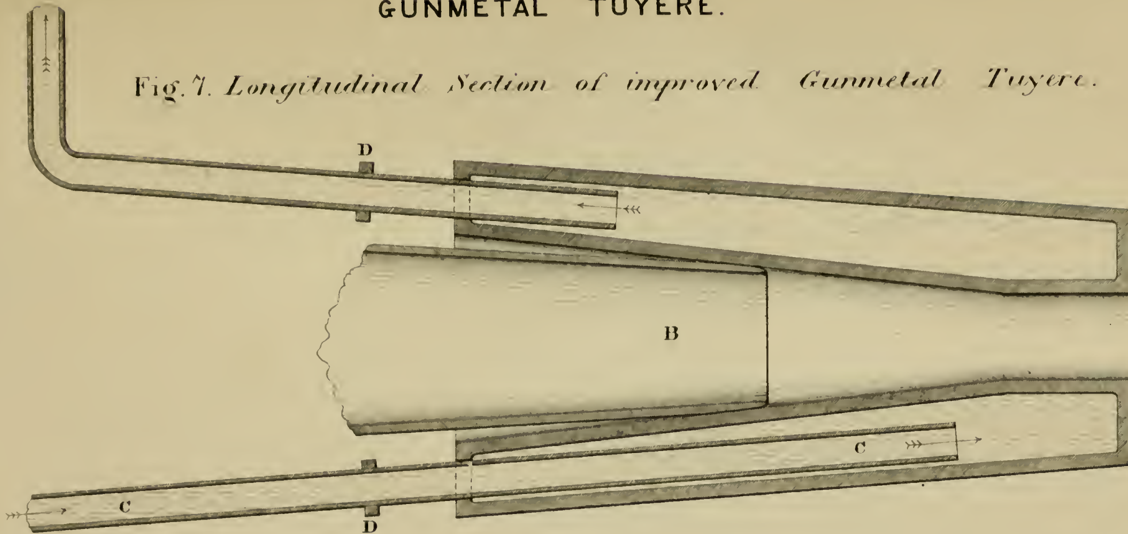
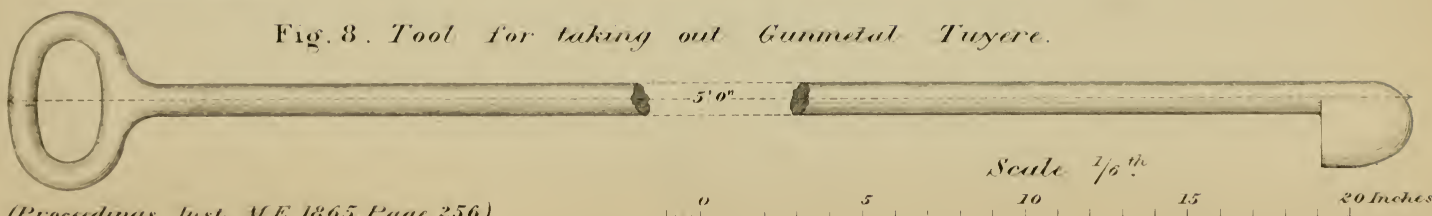


Fig. 8. Tool for taking out Gunmetal Tuyere.



PROCEEDINGS.

2 November, 1865.

The General Meeting of the Members was held in the Lecture Theatre of the Midland Institute, Birmingham, on Thursday, 2nd November, 1865; Henry Maudslay, Esq., Vice-President, in the Chair.

The Minutes of the last Meeting were read and confirmed.

The Chairman announced that the President, Vice-Presidents, and five Members of the Council in rotation, would go out of office in the ensuing year, according to the rules of the Institution; and that at the present meeting the Council and Officers were to be nominated for the election at the Anniversary Meeting.

The following Members were nominated by the meeting for the election at the Anniversary Meeting:—

PRESIDENT.

Joseph Whitworth, . . .	Manchester.

VICE-PRESIDENTS.

(Six of the number to be elected.)

John Anderson, ...	Woolwich.
Charles F. Beyer, ...	Manchester.
Frederick J. Bramwell, . .	London.
William Clay, ...	Liverpool.
Edward A. Cowper, . . .	London.
Robert Hawthorn, ...	Newcastle-on-Tyne.
Sampson Lloyd, ...	Wednesbury.
Henry Maudslay, ...	London.
John Ramsbottom, . . .	Crewe.
C. William Siemens, . . .	London.

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COUNCIL.

(*Five of the number to be elected.*)

Alexander Allan, ...	Perth.
Charles Edwards Amos, . . .	London.
Peter D. Bennett, ...	Westbromwich.
John Fernie, ...	Leeds.
Sir Charles Fox, ...	London.
Thomas Hawksley, ...	London.
Edward Humphrys, ...	London.
James Kitson, ...	Leeds.
Walter May, ...	Birmingham.
John R. Ravenhill, . . .	London.
John Robinson, ...	Manchester.

The Chairman announced that the Ballot Lists had been opened by the Committee appointed for the purpose, and the following New Members were duly elected:—

MEMBERS.

Charles C. Beardshaw, . . .	Sheffield.
John Bell, ...	Manchester.
John Cartwright, ...	Birmingham.
Matthew Curtis, ...	Manchester.
Benjamin Davies, ...	Chorley.
Henry Dircks, ...	London.
Robert Dyson, ...	Rotherham.
John McFarlane Gray, . . .	Liverpool.
William Harrison, ...	Blackburn.
William Smith Longridge, . .	Ambergate.
John Maylor, ...	Rio de Janeiro.
William Pratchitt, ...	Carlisle.
Robert Robey, ...	Lincoln.
Christer Peter Sandberg, . .	Stockholm.
Edward Scott, ...	Manchester.
William Sellers, ...	Philadelphia, U. S.

John Tickle, ...	Westbromwich.
Edward Toomey, ...	Dublin.
John James Trow, ...	Wednesbury.
Albert Vickers, ...	Sheffield.
William Wainwright, ...	Worcester.
James Edwards Wilson, . . .	London.
Clifford Etches Winby, ...	Cardiff.

HONORARY MEMBERS.

Frederick Barker, ...	Leeds.
David Parry, ...	Leeds.
Joseph Whitley, ...	Leeds.

The Chairman announced that an Honorary Life Membership in the Institution had been conferred by the Council, in accordance with the power given by the rules, upon Dr. Downing, Professor of Engineering in the University of Dublin, as a mark of their feeling of the great obligation to him for the important and valuable aid rendered by him on the occasion of the Dublin Meeting of the Institution, as well as in acknowledgment of his contributions to Engineering Science.

The following paper was then read:—

ON AN IMPROVED SAFETY VALVE FOR STEAM ENGINE BOILERS.

By Mr. WILLIAM NAYLOR, of London.

The subject of this paper is an improvement in the construction of the Safety Valves at present in use on locomotive marine and stationary engine boilers, for the purpose of preventing the pressure of the steam whilst blowing off through the safety valve from rising beyond the limit to which the valve is adjusted. This rise of pressure during blowing off is found to take place to a greater or less extent in all steam boilers with the ordinary safety valves, including locomotive marine and stationary boilers; but it occurs especially with locomotive boilers, where the safety valves are pressed down by levers with spring balances at the extremity, and the rising of the valve in blowing off causes a lifting of the lever and a considerable extra extension of the spring balance and consequent increase of pressure upon the valve.

From experiments made by the writer with locomotive boilers, he believes that a clear available opening of 7-10ths of a square inch will allow the steam to escape as fast as it can be generated in a large locomotive boiler at a pressure of 120 lbs. per square inch, when the engine is not consuming steam by running, and with the help of a steam jet in the chimney. Taking the theoretical velocity of steam at that pressure issuing into the atmosphere as 1900 feet per second, the practical velocity of the issuing steam, allowing for its friction in passing the safety valve and the resistance of the atmosphere into which it has to flow, may be assumed at 70 per cent. of this amount or 1330 feet per second. This velocity with the above-named opening of 7-10ths of a square inch gives a discharge of 11,172 cubic inches of steam passing off per second. Taking the

relative volume of steam to water at that pressure as 203 times, this is equivalent to an evaporation of about 12 gallons of water per minute (11·94); or a consumption of about 8 cwts. (7·99) of coal per hour, taking the evaporative duty at 8 lbs. of water per lb. of coal. This extent of evaporation and consumption the writer believes to be the maximum that could be attained under extreme circumstances in locomotive boilers.

The present large locomotive boilers are made some with two safety valves of $3\frac{1}{2}$ inches diameter, some with two valves of 4 inches diameter, some with two of 5 inches diameter, and some engines are working with four valves of 3 inches diameter; the valves being loaded by spring balances through levers, or in some cases by a spring acting direct, without the intervention of a lever. When the spring balance and lever are used, the proportions of the lever are generally arranged so that 1 lb. pressure of the balance is equal to 1 lb. per square inch on the valve; and then the perpendicular lift of the valve in opening multiplied by the number of square inches in its area gives the distance that the outer end of the lever has to move to allow the required opening of the valve; and this lift of the lever end multiplied by the number of lbs. to the inch in the graduations of the spring balance gives the number of lbs. per square inch of additional load put upon the valve by the act of lifting, and the corresponding increase of pressure necessitated in the steam to admit of its escape through the opening of the valve, in addition to that required for overcoming the friction of the steam in passing the valve and the resistance to it in flowing into the atmosphere.

Taking the case of two valves of 5 inches diameter, giving a combined circumference of 31·4 inches, and say 30 lbs. to the inch as the graduation of the spring balances, with a ratio of leverage (or area of valve) of 19·63 to 1, a total area of discharge of 7-10ths square inch would require a lift of the valves of $\frac{0\cdot7}{31\cdot4}$ or ·0223 inch; but as the bearing faces of the valve and seat are not horizontal but inclined at 45°, a vertical lift of the valve equivalent to 1 square inch (0·99) annular area is required for giving a discharging area of 7-10ths square inch; and the total lift will therefore be ·032 inch. This gives an extension of the spring balance of ·032 × 19·63 or ·628

inch, causing an extra load upon the valve of ·628 × 30 or 18·8 lbs. per square inch in order to get the required opening for discharge of the steam. The result is therefore that, in order to give a sufficient area of opening for the discharge of all the steam that the boiler is capable of generating, the pressure must rise in the boiler about 19 lbs. per square inch above the intended limit of the working pressure, or the point at which the safety valves are adjusted to begin blowing off; and this action of increasing the total pressure upon the valve as the valve rises is inseparable from all arrangements in which the valve is pressed down by a spring acting either through a constant lever or direct upon the valve.

The improved Safety Valve forming the subject of the present paper has been designed by the writer for the purpose of removing this defect, by causing the spring that presses upon the valve to act not through a constant lever, but through one which varies in its effective length, diminishing in length as the valve rises in the same proportion that the tension of the spring is increased by the rising of the valve, so as to prevent any increase taking place in the total pressure upon the valve.

The improved valve is shown in Figs. 1 to 4, Plates 63 and 64, Fig. 1 being a vertical section, and Fig. 2 a sectional plan.

The safety valve A is only 2 inches diameter inside the seating, and is pressed down by the inverted spiral spring B acting upon the opposite end of the bent lever C, the effective length of lever being $2\frac{1}{2}$ inches at the valve and $1\frac{3}{4}$ inches at the spring. When the valve rises, the bearing point of the spring at the end of the lever, being inclined downwards at an angle of 35° from the vertical line D in Fig. 3, is deflected nearer to this vertical line by the lifting of the valve end, as shown by the dotted position in Fig. 3; and the result is that the effective leverage at which the spring acts is reduced to the extent required to compensate for the increased tension of the spring caused by the motion of the lever, so that the total pressure upon the valve remains unaltered. The centre E on which the lever works is a knife-edge, so as to prevent its action from being interfered with by friction from the heavy pressure upon

it, which is nearly double the pressure of the spring; and the connection of the spring to the lever at F is by a knife-edge also, Figs. 3 and 4, in order to give complete freedom of action to the whole. The spiral spring is made of $\frac{3}{8}$ inch round steel, and the pressure upon the valve is adjusted by screwing up the spring by the nut G, the highest pressure being limited by a solid collar upon the spindle. Any accident from failure of the spring is provided against by the lower end of the lever then coming in contact with the casing at H, Fig. 3, which prevents any risk of the valve becoming displaced.

This valve being only 2 inches diameter with a circumference of 6·28 inches, the height to which it must be lifted in order to give the same area of discharge as before, 7-10ths of a square inch, is $\frac{1}{6 \cdot 28}$ or ·159 inch; and the valve end of the lever being $2\frac{1}{2}$ inches long, this requires an angular movement of the lever of 3° 39′. The angle between the spring end of the lever and the vertical is consequently reduced from 35° to 31° 21′; and taking the horizontal distance $1\frac{3}{4}$ inches or 1·75 inches as the sine of the former angle, the sine of the latter angle will be 1·59 inches, making a shortening of ·16 inch in the leverage at which the spring acts. The difference between the cosines of these angles to the same radius, or ·106 inch, will be the extension of the spring produced by the same range of motion; and the area of the valve being 3·14 square inches, the total pressure of the spring to give a pressure upon the valve of 120 lbs. per inch will be 538 lbs. with the original leverage of 1·75 inches, and with the reduced leverage of 1·59 inches the total pressure required at the spring is then 593 lbs. Hence an increase of 55 lbs. in the total pressure of the spring has to be produced by the extension of ·106 inch in length caused by the motion of the lever, in order to maintain a constant pressure upon the valve; and this gives 519 lbs. per inch deflection for the strength of spring required for the purpose.

In practice the spring is adjusted so as to give a slightly reduced total pressure upon the valve when fully open, the pressure per square inch on the valve being made about 4 per cent. less when the valve is blowing off strongly than when the valve is shut; in

order to compensate for the effect of the friction of the large quantity of steam passing in that case through the narrow opening of the valve. It has been found by careful trials with this valve that, when the steam is blowing off very strongly, the pressure within the boiler exceeds the load upon the valve by about 5 per cent.; and therefore by proportioning it as above with 4 per cent. less pressure of the spring upon the valve when open than when closed, the occurrence of any sensible increase of pressure within the boiler beyond the limit at which the valve is set is completely prevented. At the same time it is found that the valve closes again after blowing off strongly, without allowing any sensible fall in the boiler pressure below that limit.

This improved valve therefore effectually provides for the prevention of any increase of pressure occurring under any circumstances in the boiler beyond the intended limit of pressure; and the one valve, although only 2 inches diameter, gives the full area for discharge of the steam obtained with the two large valves ordinarily used. The one valve may consequently be considered as fully equivalent in safety to the two ordinary valves, although it may be preferred still to adopt the precaution of employing two valves.

In the case of the two ordinary safety valves of 4 inches diameter, having a combined circumference of 25·1 inches, and a ratio of leverage of 12·57 to 1, a total increase of pressure of 15·0 lbs. per square inch will be caused in giving the required full area of opening of 7-10ths square inch for discharge. And with two valves of 3 inches diameter, having a combined circumference of 18·8 inches, and a ratio of leverage of 7·07 to 1, the total increase of pressure will be 11·3 lbs. per square inch.

It appears therefore that, with the ordinary construction of safety valves, the larger size of valves, instead of giving increased freedom to the discharge of the steam, are actually inferior in this respect to the smaller valves, the two 5 inch valves allowing an increase of pressure of 18·8 lbs. per inch during the escape of the steam, whilst the two 3 inch valves allow only 11·3 lbs. per inch

increase with the same discharge. This arises from the circumstance that the pressure required to hold down the valve increases as its area or as the square of its diameter, whilst its area for discharge increases only as its circumference or directly as its diameter. This result is also not altered in the cases where, instead of using a lever with a spring balance at the end, a large spiral spring is employed pressing direct upon the valve, or between two valves, the pressure of the spring and its motion being then the same as those of the valve, instead of the pressure of the spring being diminished and its motion increased both in the same ratio by the action of the lever.

The improved valve possesses an important advantage over most forms of the ordinary valves, from the circumstance that it is quite impossible for the valve to be tampered with by the enginedriver so as to increase the pressure beyond the intended limit; and in the writer's personal knowledge the frequency of this occurrence with ordinary valves is much greater than is generally supposed.

One cause of extra pressure in locomotive boilers occurs when an engine is proceeding with a train, with the steam well up and a good fire, and it is suddenly checked by a danger signal being exhibited, and the engine has to be reversed. In such a case, whilst the fire is generating steam vigorously, the cylinders instead of using it are converted into air pumps, pumping air into the boiler at every stroke. The steam generated must all pass off by the safety valves, and the pressure often rises considerably above the limit at which they are adjusted.

When an engine is taking a heavy load up an incline slowly, the steam blowing off strongly, as much as 40 lbs. excess of pressure has occurred within the writer's experience, without the safety valves being interfered with. The writer has also known the case occur of a large goods engine coming to a stand on an incline from want of power, although the steam was blowing off very strongly; and the driver being afraid to go back from fear of a collision, has secured the valves against blowing off, by pegging down the levers

in the slots through which they passed in the weatherboard. The regular working pressure was 120 lbs., but the steam got up to 180 lbs. per inch by the pressure gauge, and the engine was then able to take the train to the top of the incline.

Another source of risk of extra pressure is when an engine is having the steam got up in the engine shed, and to hasten it the steam jet has been put on and left on while the fire-lighter is gone to look after other engines. From a number of experiments the author has ascertained that, if the jet be left full on for six minutes after the steam begins to blow off, there will be an excess of pressure in the boiler of at least 30 lbs. per square inch over what the safety valves on the ordinary construction are loaded at.

In the case of marine boilers it is required by the government regulations that there shall be at least one safety valve upon each boiler loaded direct by weights, and that the area of this valve shall be one circular inch for every horse power nominal; so that a boiler supplying steam equal to 100 horse power requires a safety valve 10 inches diameter. But although these valves are loaded by direct weights, the pressure in the boiler will necessarily exceed the load on the valve when the steam is blowing off in great force, which is liable to occur occasionally when the engines are stopped, from neglect in not easing the pressure at that time. There is however a serious defect in this mode of loading safety valves on marine boilers, from the circumstance that when the vessel rolls the pressure of the weight is diminished; and if it rolls to the extent of 45° there will not be more than 70 per cent. of the full load upon the valves at that moment, and consequently there will be a loss of power when the greatest power may be required. Moreover the water in the boiler is subjected to violent commotion by the repeated starts of ebullition from the pressure being suddenly reduced by the lifting of the safety valve; and this commotion is not at all times stopped by the closing of the valve, but produces priming in the cylinders. With the improved valve however the full pressure would be preserved steadily in the boilers, with any extent of rolling of the vessel.

On the boiler of a stationary engine a comparative trial has been made of one of these valves of only $1\frac{9}{16}$ inch diameter, and two other ordinary valves of $3\frac{3}{8}$ inches diameter, loaded one with dead weights and the other with a lever and spring balance, all the valves being adjusted so as to begin blowing off at the same pressure. The engine was stopped and the firing of the boiler continued, and the steam generated had all to escape through the safety valves. The valve loaded by a lever and spring balance did not appear to increase in the amount of steam passing by it, and the valve loaded by dead weights increased in extent slightly; but the improved valve increased to a perfect roar, thereby telling its own tale as to which valve was carrying away the steam. When the damper was closed and the firedoor opened, all the valves ceased blowing off at the same time.

The number of boiler explosions that have occurred from over pressure show the necessity of some effective means being adopted to prevent that occurrence; and if a boiler be at all defective in construction or have become so after long use it is the more necessary that it should be provided with safety valves which will render it safe against any excess of pressure occurring beyond the amount required for working the engine. All surplus pressure put upon a boiler through the defect of the safety valves not being able to carry away the steam as fast as generated is tending to positive destruction without any advantage; and if the boiler has a sufficient margin of strength to resist such surplus pressure as it is subjected to with the ordinary arrangement of safety valve, the use of a valve that will maintain a uniform pressure would have the advantage of allowing an increased pressure to be regularly used in the engines.

Mr. Naylor exhibited specimens of the safety valve, and explained that in the case of valves constructed for marine boilers an india-rubber diaphragm was fixed across the bottom of the chamber containing the spring, as at II in the 5 inch marine safety valve

shown in Figs. 5 and 6, Plate 65, so as to protect the spring from the corrosive action of any salt water thrown out from the boiler with the steam in blowing off, in consequence of the rolling of the vessel. This provision was not necessary in the valves for locomotive or stationary boilers, because in these cases the steam blowing off from the valve passed direct up the funnel placed over the valve, and any water carried off along with the steam by priming was blown out through the funnel in the same way, so that neither steam nor water was found to get to the spring.

The Chairman enquired how many of the new valves were now in use, and where they were at work.

Mr. Naylor replied that there were now about forty of the valves in use, most of which were on locomotive boilers, principally upon the Great Northern Railway. In the first adoption of the new valve upon that line, the size of the valve seemed so extremely small, in comparison with the safety valves previously employed, that a special trial was made to test the sufficiency of the new valve. One of the new valves of 2 inches diameter was fixed on a locomotive boiler, and the two ordinary valves of 4 inches diameter previously used were removed: the engine had a large firebox, and in order to increase the generation of steam an additional length of funnel was attached above the chimney, and a steam jet was added in the smokebox. By this means a very rapid generation of steam was obtained, producing a great blow-off at the valve; but it was found that even under these extreme circumstances the pressure in the boiler could not be raised to as much as 10 lbs. above the limit at which the valve was set to blow off. In a trial made with one of the new valves of $1\frac{1}{8}$ inch diameter, the result had not been satisfactory, because the valve had not been made with lift enough in that particular case; but from experiments subsequently made he was satisfied that a valve of only that size was amply sufficient in practice for a locomotive boiler, when arranged so as to allow the full lift required to give the necessary area of opening for blowing off; and the principle of the bent lever afforded the means of obtaining any amount of lift, without increasing the pressure upon the valve by the extension of the spring.

Mr. F. J. Bramwell thought the new safety valve was a very ingenious practical contrivance for getting over the defects of the ordinary construction of safety valves, and allowing the steam to blow off in any quantity with complete freedom at the intended limit of pressure. The defects in the principle of ordinary safety valves acted on by spring balances arose from two causes, the first being the extra pressure put upon the valve in blowing off, owing to the extension of the spring and the additional force consequently exerted by it; and although theoretically this extra pressure might be reduced to any extent by using a spring of greater length and consequently greater elasticity so as to give less increase of pressure with the same extent of stretching, yet in practice very little improvement could be effected in this way, as the total length of spring that could be employed was limited by practical considerations of convenience; and in the case of locomotive boilers it was not practicable to employ springs having much more elasticity than those at present generally used, which gave a force of not less than 20 lbs. per inch of extension. The second defect attendant upon ordinary safety valves arose from the circumstance that, at the time of blowing off, the pressure of the steam in the immediate neighbourhood of the aperture of the valve was reduced by the rapidity of the motion of the escaping steam; and consequently, in order that the valve might be held open for blowing off at the intended limit of pressure, it was necessary that the steam pressure within the rest of the boiler should have risen considerably above that limit, in order to keep the reduced pressure at the aperture of the valve up to that limit. Both of these defects in ordinary safety valves were completely met by the principle of construction of the new valve, in which the adoption of the bent lever not only allowed of the valve being lifted to the full extent without any increase of pressure being put upon it by the extension of the spring, but also afforded the means of actually diminishing the load upon the valve in lifting, to any extent that might be found necessary to compensate for the diminished pressure of steam at the aperture in blowing off. The principle of the bent lever thus caused the safety valve to blow off with certainty at the intended limit of pressure, without allowing the

steam in the boiler under any circumstances to rise beyond that limit by more than the small fixed percentage determined by the original adjustment in the proportions of the lever and strength of the spring.

Mr. NAYLOR remarked that the rise of pressure in blowing off with ordinary safety valves was also partly due to the resistance offered by the atmosphere to the escape of the issuing steam; and he thought the amount of this resistance was considerably greater than it was generally believed to be. For it was evident that in the case of a safety valve loaded by a dead weight instead of by a spring, if there were no resistance offered by the atmosphere to the escape of the steam, the steam would blow off with perfect freedom and the pressure would never rise above the intended limit, since the valve would lift to any required extent without the load upon it being thereby increased. But in practice it was found that this was not the case; for with an ordinary safety valve of 5 inches diameter loaded by a dead weight upon a boiler 25 feet long he had found that there was as much as 8 to 10 per cent. increase of pressure beyond the limit at which the valve was set to blow off; and he believed this was due to the resistance met with by the steam in issuing into the atmosphere.

Mr. F. J. BRAMWELL did not think the resistance offered by the atmosphere to the issuing steam was by any means so great as to account for an increase of pressure of 8 to 10 per cent. beyond the intended limit; but he considered this increase of pressure in blowing off was almost entirely due to the circumstance which he had previously mentioned, the velocity of the escaping steam causing the pressure to be so much reduced in the immediate neighbourhood of the valve, that in order to maintain the pressure at the valve up to the intended limit it was necessary for the pressure in the rest of the boiler to rise considerably above that limit. In accordance with this view of the question a construction of safety valve had been employed upon some boilers, having a slide valve worked by a piston; and the piston being acted upon by the steam pressure inside the boiler, at some distance from the aperture of the slide valve, opened the slide at the intended limit of pressure and kept it open, without requiring the pressure to exceed the limit.

The Chairman enquired what was the cost of the new safety valves, in comparison with ordinary safety valves having levers and spring balances.

Mr. Naylor replied that the difference of cost of the new safety valves as compared with the ordinary valves was very little. The two new valves exhibited were each $2\frac{1}{2}$ inches diameter and were intended for locomotive boilers: the one with brass funnel and brass chamber for containing the spring cost £10 10*s*., and the other made of iron with gunmetal valve and valve-seat cost £9. The new valves were much lighter than the ordinary valves of larger size, used for the same situations, with their levers and spring balances.

Mr. F. J. Cannell thought the new safety valve was of very great advantage for boilers in ironworks heated by the puddling furnaces, where it constantly occurred that the steam was suddenly shut off from the engine while the furnaces required to be kept in full work; and in such cases it was of the utmost importance to have the means of blowing off through the safety valve the whole of the steam that the boiler could generate. At the Old Park Iron Works, Wednesbury, they had had one of the new safety valves of 2 inches diameter at work for six months on one of the locomotives working at 85 lbs. pressure, and it had given complete satisfaction; the engine had often stood still for $\frac{3}{4}$ hour with a full fire, and the steam had been so effectually carried off by the safety valve that the pressure in the boiler had not risen 1 lb. above the limit of 85 lbs. at which the valve was fixed to blow off; whereas in other boilers having ordinary safety valves with levers and spring balances the pressure rose 15 or 16 lbs. above that limit under similar circumstances. He had paid great attention to the working of the new valve, and was satisfied that it effectually prevented any rise of pressure in the boiler above the fixed limit.

Mr. W. Ford Smith remarked that, on one occasion of taking to pieces for repairs an ordinary locomotive safety valve with lever and spring balance, he had found that the centre pin of the lever, having been carefully fitted in the first instance, had become rusted so tightly in the eye that it required an additional force of probably 60 to 80 lbs. at the end of the lever to lift it; and he was therefore

glad to see that pins were done away with in the new safety valve, a simple knife-edge bearing alone being employed as the fulcrum for the bent lever. He enquired whether the valve was guided in lifting by a centre spindle inside the boiler, because he had found that mode of guiding was also liable to the objection of the spindle becoming corroded in the guide, and he had seen safety valve spindles so encrusted in the guides that it was impossible for the valve to lift at all.

Mr. Naylor explained that in the new safety valve the valve itself was guided by three wings cast upon it, and not by a spindle; it was then not liable to become stuck by corrosion, and the only objection experienced in guiding by wings was when the valve seating was composed of a brass bush let into an iron seat, in which case the brass bush being unable to expand freely outwards became tightened upon the valve and caused the wings to bind in the seating, so that the valve could not lift. In the new valves however the seating was always made entirely of brass, so that there was no tendency to nip the wings of the valve in expanding.

In reference to the knife-edge bearing of the bent lever, the use of the knife-edge was very advantageous in reducing the extent of the bearing surface and thereby getting rid of the friction inevitably attending a round pin. The square centre pin forming the knife-edge bearing was fixed in the valve casing, so that it could not turn in its place; and the width of the bent lever was sufficient to ensure the knife-edge bearing holding it steady from any lateral twist in working.

A point of great practical importance in the new safety valve was the impossibility of tampering with the valve, as there was no external projecting lever which could be pegged down in its slot holes or loaded with additional weight; but the valve was entirely boxed up, and could not be got at by the enginedriver in any way.

Mr. J. Tomlinson observed that it could only be owing to bad management if the levers of ordinary safety valves became rusted in their bearings, and he had found it necessary to have all locomotive safety valves taken to pieces regularly once every three months for examination and cleaning; and if the same plan were

carried out in other cases there would be no danger of the valve becoming corroded fast. In the new safety valve he thought there appeared a possibility of dirt getting into the closed part of the valve casing in which the bent lever worked, and so causing it to stick fast; and he enquired whether any difficulty had been experienced with the new valve in this respect. He asked also whether the fact of slightly relieving the load upon the valve in blowing off did not cause the steam pressure in the boiler to fall below the intended limit before the valve could be closed again by the spring. In the case of a locomotive boiler working with 120 lbs. steam, he should expect that the pressure would have to fall 6 or 7 lbs. below the limit before the valve would close again after blowing off.

Mr. Naylor replied that the pressure of steam in the boiler did not fall below the limit in blowing off, because as the violence of the blowing off subsided the valve gradually closed; and the spring and bent lever were so adjusted that the valve shut again exactly at the fixed limit of pressure. It was of course possible by altering the adjustment of the bent lever to relieve the load off the valve to such an extent when lifted, that it should not close again until the pressure had fallen to a given percentage below the limit; but in practice this had not been found desirable.

In regard to the lever becoming obstructed by dirt getting into the valve, this had not been found to occur with any of the valves yet in use; and he thought any dirt getting in at the funnel of the valve would be blown out again by the steam in blowing off. There was no reason to apprehend that the knife-edge bearing could become stuck fast by dirt, as it could not be made a tight fit like a centre pin; and the extent of bearing surface was so small that there was no room for particles of dust or dirt to collect in sufficient quantity to obstruct the free action of the valve.

Mr. F. W. Webb remarked that the only way in which there appeared any possibility of tampering with the new valve was by driving a plug in at the top of the funnel over the valve, to interfere with its opening; or by dropping in a heavy weight upon the valve to increase the load upon it; and so much ingenuity had been

displayed by enginedrivers in tampering with previous safety valves, that it was very desirable to provide against any such attempts with the new valve.

Mr. Naylor said it was proposed to fix a cover of strong wire gauze at the top of the funnel over the valve, to prevent the possibility of tampering with it in any such manner as had been suggested.

The Chairman proposed a vote of thanks to Mr. Naylor for his paper, which was passed.

The following paper was then read:—

ON AN IMPROVED METHOD OF TAKING OFF THE WASTE GAS FROM OPEN-TOPPED BLAST FURNACES.

By Mr. GEORGE ADDENBROOKE, of Darlaston.

The utilisation of the Waste Gas from Blast Furnaces has now become not only an accomplished fact but a great commercial success, and consequently an important part of furnace management. This gas, or rather mixture of gases, issues in large quantities from all the interstices between the last charge of materials in the furnace throat; and it passes off with such rapidity as to prevent a sufficient mixture of air taking place to render it inflammable until it has risen to some little height above the top of the materials in the furnace mouth. As soon however as this mixture of air takes place, a very considerable portion of the gas is consumed, in the case of the ordinary open-topped furnaces that do not utilise the waste gas. This combustion develops a great amount of heat; and the question therefore arises, how can the waste gas be made further useful, without in any way injuring the yield, the working of the furnace, or the quality of the iron made; for if any injury were occasioned in either of the above respects by taking off the waste gas, the utilisation of the gas ought certainly not to be attempted. It is evident that there must always be an escape of surplus gas from the top of the materials in the furnace throat, from the consideration that the heat in the lower part of the furnace distils off the gas from the fuel in the upper part; and this gas, not meeting with a supply of oxygen inside the furnace, passes up unconsumed to the furnace mouth, where upon mixing with the external air it burns away to waste, unless taken off previously in order to be usefully burnt elsewhere.

The utilisation of the waste gas has been extensively carried out in two different modes, each capable of being applied and worked in several different ways. The one mode is known as the Close-Top system, and the other as the Open-Top system. Till the last few years however the writer believes that in no case was the waste gas successfully utilised in Staffordshire, though this had been effected a good many years previously in some other districts. The chief reasons for this continued waste of the gas in Staffordshire may be found in the cheapness of engine fuel, causing the mistaken idea to be entertained that it was cheaper to burn the slack under the boilers than to go to the expense of saving an article which would not be saleable; and also in the great dislike that all connected with the working of furnaces have to any considerable change in system.

The writer's attention was particularly called to the subject of utilising the waste gas from blast furnaces about five years ago, when he was engaged with others in examining the subject, and visited for the purpose many works where the utilisation was carried on at one or more of the furnaces. The decided opinion then arrived at was that the waste gas ought certainly to be utilised, and for the following reasons:—namely, that a furnace would work to better yield where the gas was utilised, and with greater regularity as to the quality of iron made; and that there would be a very considerable saving in repairs to hot-blast stoves and boilers by heating these with the waste gas, together with greater regularity in the heat and pressure of the blast, because of a more even temperature being maintained under the boilers and in the stoves; while there would also be a considerable saving in wages, and the men would be made more regular in charging the furnace.

The principle upon which the waste gas is taken off in the case of the close-topped furnaces is that, by keeping the furnace top closed, the gas must necessarily pass away through any openings which are made for its escape, and may thus be made to travel even to a distance of more than a quarter of a mile from the furnace, as is done at the Dowlais Iron Works. In the open-topped furnaces the idea is that, after the gas has done very nearly all its work in the

furnace, on arriving within about 5 feet of the top of the materials in the furnace mouth the greater part can be drawn off from the furnace by applying a mild suction, and employed to advantage for heating purposes elsewhere; at the same time, as no considerable amount of force is used for drawing off the gas, either by the suction of a chimney or otherwise, all surplus gas generated in the furnace beyond the amount drawn off escapes at the open top of the furnace, by passing up through an average of $3\frac{1}{2}$ feet depth of charged materials above the point of taking off the gas.

The open-topped plans of taking off the waste gas may here be divided into two classes:—those taking off the gas at a less depth than 5 feet below the top of the materials in the furnace throat; and those taking it off below that level. In the former the gas is taken off with due regard to the effect on the yield and working of the furnace; while in the latter the utilisation of the gas is made the chief object.

In order to carry out the utilisation of the gas without risk of interfering with the successful working of the furnace, it is of very great consequence not to take off the whole of the gas, but to leave a certain portion always to escape at the furnace mouth, so that it may continue the process of preparing the newly charged materials, and begin to dry and warm them immediately upon their being charged, and also prevent any downward current of air taking place from the furnace top. Such a downward current of air must necessarily take place frequently, where the whole of the gas is drawn off; as the chimney power requisite for this purpose would be quite sufficient to draw down the air through the average depth of $3\frac{1}{2}$ feet of materials in the furnace throat above the gas openings, at any time when there was not an ample supply of gas to be drawn off. The result would then be that where the ascending gas and the descending air met in the furnace a bright flame would be produced, which taking place amongst the fuel must occasion a very serious loss, by causing combustion of the fuel before it reaches the part of the furnace where its combustion is useful; and it appears doubtful whether fuel thus once lighted would not continue

smouldering the whole of the way down in the furnace. On the other hand if the fuel is properly covered in the upper part of the furnace by a sufficient depth of materials, so as to be protected from the air, the writer doubts whether it will begin to burn till it reaches the zone of fusion, where it then changes from a mere highly heated state to one of active combustion caused by the presence of air supplied from the tuyeres. The writer believes that in the fact of covering up the fuel, without ignition being allowed to take place, lies one of the chief sources of saving in the yield of the fuel; and he considers that it is this alone in the close-topped furnace, which to a very great extent makes up for the loss of yield of fuel that must inevitably result from the use of the close-topped system with its consequent back pressure. This saving however is more than counterbalanced by the fact that neither drying nor warming nor any other preparation of the materials can be carried on in the close-topped furnace except by the heat of the gas coming up from below.

Were it not for the back pressure produced in the furnace by a closed top, this system would doubtless work to a much better yield than the open top; but the entire prevention by the closed top of any drying or warming of the materials taking place until they have descended some distance within the furnace is a serious objection in the writer's opinion to the close-topped plan; whilst on the other hand in a well worked open-topped furnace the preparation of the materials begins at once upon their being charged. Moreover there is no way of so regulating the "driving" of a furnace or rate of descent of the materials in the interior as that in every hour the furnace shall take the same quantity of blast; but whenever the steam pressure happens to rise above the average, causing the engine to force more blast into the furnace, or whenever the materials happen to lie more open in the furnace or to be drier, an increased driving of the furnace will be occasioned, which will give an increased production of gas to pass off from the furnace. As this larger quantity of gas has in the close-topped furnace to pass off through the same openings which previously carried off a smaller quantity, the result must be an increase of the back pressure in the furnace;

whereas with an open top the surplus gas readily escapes at the mouth of the furnace, without producing any back pressure inside the furnace. Another objection to the closed top is that the pressure coming from the lower part of the furnace will carry off with it from the furnace more dust than would be drawn off by suction.

The desideratum in the utilisation of the blast furnace waste gas appears therefore to the writer to be an open top where the fuel can be buried or covered, without its being ignited to any material extent either by the escaping gas, or worse still by the gas being drawn off so completely from the furnace throat that air is drawn down also through the materials, causing a hidden fire to be raging beneath the surface of the materials while everything seems to be going on well. The writer has indeed frequently seen the gas drawn off so completely that a man could walk inside the mouth of a large furnace while the blast was on; but experience shows that such a state of the furnace top is altogether wrong, and if ever it occurs the main gas valve ought at once to be closed sufficiently to ensure some gas passing off at the furnace top, in order to begin the preparation of the materials and prevent any downward current of air.

The level at which the gas is taken off from the furnace is in the writer's opinion a most important point, as in effect the working height of the furnace nearly terminates at the level where the gas is taken off. The most satisfactory working that the writer has known of a blast furnace has been where the gas was partially and not wholly taken off and at a depth of 4 ft. 6 ins. below the top of the materials. In one case that came under his experience, one of Darby's bells was used very successfully for a considerable time, taking off the gas at a depth of 4 ft. 6 ins. below the top; but when it became necessary to change it, the new bell was inserted to a depth of 5 ft. 6 ins., in order to give the fillers a little more range of level; this was however found to work so much less satisfactorily that it was altered back again to the original depth of 4 ft. 6 ins.

The very great sensitiveness of a furnace to the least lowering of its working height is undoubtedly the cause of more than one half of the mottled and white iron that is made where grey forge or forge iron was expected. The change is usually caused by delay in filling, most frequently at night, when the men often neglect their work and allow the furnace to drive, so that the surface of the materials is lowered a considerable distance; and the effect is then observed about three casts later by the production of mottled or white iron. The worst consequence of this neglect is that the furnace manager then finding white iron made probably alters the burden at once in order to correct the fault; and after charging it up to the next casting time with either less ore or more fuel, he probably finds this next cast all right, and therefore alters the burden back again; but in another cast or two comes the iron made from the lighter burden, rather too grey to suit the purposes it is wanted for. With a closed top there can be no check upon irregularity in filling, day or night, except by constantly watching the filling. But in an open-topped furnace where the gas is taken off through openings not lower than 5 feet below the top of the materials, if the filling were delayed more than half an hour, the greater portion of the gas would begin to escape at the furnace mouth instead of being drawn off through the gas openings, as the surface of the materials would be lowered nearly to the level of the gas openings. The fillers' neglect would then be detected by an increased flame from the furnace mouth, and by the supply of gas to the boilers and hot-blast stoves falling short; and they would be recalled to their duty by the risk of all coming to a standstill from stoppage of the blowing engine.

This great sensitiveness of blast furnaces as to being kept charged full appears to suggest strongly the doubt whether the Staffordshire furnaces are now as high as the fuel would allow of their being worked profitably; and whether a gain of yield would not be found to result from raising the furnaces. The present height of from 40 to 50 feet in Staffordshire has been increased in the Cleveland district up to 80 feet and more, and it is considered the limit of height has not yet been arrived at in that district.

There is no doubt that the Staffordshire fuel would not stand any very considerable increase of height, on account of its friability; but it would at least be desirable to ascertain by trial whether some increase of height would not be beneficial.

The result of the previous enquiries in which the writer was engaged as to the best mode of utilising the waste gas from blast furnaces was the adoption of the open-topped plan with Darby's bell inserted in the neck of the furnace to a depth of 4 ft. 6 ins. below the surface of the materials; and the writer has much pleasure in acknowledging the good service rendered in connection with the South Staffordshire iron district by the introduction of this plan to notice in the valuable paper read upon the subject at a former meeting of the Institution five years ago, (see Proceedings Inst. M. E., 1860, page 251). This plan was applied to two furnaces at the writer's works at Darlaston; and in carrying it out the special points attended to were to provide a large gas main, a large chimney, and large flues to the chimney. For this purpose the gas mains were made 5 ft. diameter, the chimney 10 ft. diameter inside throughout with a height of 160 feet, and the main flues to the chimney very large, 5 ft. high to the crown of the arch and 4 ft. 6 ins. wide; and experience has shown that these dimensions are none too large.

The two furnaces continued at work on this system till September 1864, when the heavy cost of repairs and renewals with the consequent stoppages and loss in wages led the writer to design the plan to be described in the present paper, which is shown in Figs. 1 to 7, Plates 66 to 70. Fig. 1, Plate 66, is an outside elevation of the furnace to which this system is applied. Fig. 2, Plate 67, is a vertical section of the same furnace, showing the gas openings A A from the furnace into the neck flue B, and the gas branch pipe with stop-valve C for connecting or disconnecting this furnace from the range of gas main. Fig. 3, Plate 68, is a sectional plan of the furnace taken through the gas openings A A and neck flue B. Fig. 4, Plate 69, is an enlarged section of the furnace top; and Figs. 5, 6, and 7, Plate 70, show a

vertical section, outside elevation, and sectional plan, of one of the segmental boxes or gas openings.

These gas openings or boxes are made of cast iron, which material has been found to stand very well, and allows of the openings being made so wide that their combined area of passage is amply sufficient for the passage of the gas, without the depth of the opening being more than 15 inches; in consequence of which they do not require to be inserted lower than about 5 feet down, and still leave a fair height of 4 feet above them for variation in the level of the top of the materials charged. The boxes are cast very strong, as shown in Figs. 5 to 7, and the openings through them are made at such a slope that nothing except very light dust can be carried through them by the gas in regular working, unless it be a bit of material thrown over by one of the slight explosions that occasionally take place where any raw minerals are used in the furnace. The boxes are placed close together side by side, so as to form a continuous ring of openings round the furnace, as shown in the plan, Fig. 3, having the lower end of the slopes opening into the furnace and the upper end opening into the large external gas flue B, Fig. 4, which surrounds the neck of the furnace. These castings take the place of so many courses of lining bricks, and after they have been fixed the lining firebricks are continued above them to the top of the furnace. Considering their strength and situation, the castings appear likely to be almost permanent. As they stand flush with the face of the lining, the whole area of the throat of the furnace is left free for charging; and when the furnace is full and any portion of the gas passing off at the surface of the materials, no damage can be done to the openings or any part of the gas apparatus. In case of the top of the materials sinking below the gas openings, any damage is prevented by shutting the gas valve C at once, when the whole of the gas will be burnt at the mouth of the furnace, but without injury occurring to any part of the apparatus, as is unavoidably the case with the wrought iron gas main proceeding from a bell inserted in the top of the furnace.

The large gas flue B surrounding the neck of the furnace is lined with firebrick, and is 4 ft. 3 ins. high to the crown of the arch

by 3 ft. mean width. The outside of the furnace from a little below the bottom of the flue upwards is cased with wrought iron plates, to which is fixed a light iron gallery D for the convenience of cleaning out the flue B. A series of openings E E are made in the outer side of the flue all round, as shown in the plan, Fig. 3, which are closed by pieces of boiler plate daubed with moistened fireclay and held in their places by crossbars and wedges; by means of these the whole of the neck flue can be cleaned out in a few minutes any time that the blast is off the furnace. The bottom of the flue is placed at a lower level than the bottom edge of the gas openings A A, Fig. 4, in order that the dust carried over with the gas may be allowed to accumulate in the flue, so long as it does not interfere with the gas openings, and it can be easily cleaned out when required. Experience of the working of this plan of furnace top proves that, from the increased area of the gas openings as compared with other plans, the gas does not pass nearly so rapidly out of the furnace, and consequently has not the power to carry nearly so much dust into the flue. The sectional plan Fig. 3 shows that there are fifteen gas openings A A round the neck of the furnace, $23\frac{1}{2}$ inches wide and $11\frac{1}{2}$ inches high on the square, each giving 270 square inches clear opening, making a total area of 4050 square inches for drawing off the gas; whereas the single central opening of the bell of 4 ft. 6 ins. diameter previously worked in the same furnace, which was as large a size as could be conveniently used, gave an area of only 2290 square inches for drawing off the gas, or only 56 per cent. of the area now obtained with the present neck openings. As the gas openings give a total area of 4050 square inches for the passage of the gas, while the descending gas main supplied by them being 4 ft. 6 ins. diameter has an area of only 2290 square inches, the velocity of the current of gas through the openings is necessarily only half what it would be where a bell or centre opening is used for drawing off the gas, as in the latter case the gas opening to the furnace cannot be made of larger area than the descending gas main of 4 ft. 6 ins. diameter.

The furnace first put to work on this plan by the writer was started in September 1864; and as fear had been frequently

expressed previously, that if the gas was taken off from the outside of the furnace instead of from the centre the working of the furnace would necessarily be injured, the work was not done at all substantially at first, but merely with cast iron plates 2 inches thick to form the gas openings, by way of trial. This fear however of drawing off the gas from the outside of the furnace within a reasonable distance of the top, instead of from the centre, appears when fairly looked into to be unfounded. For the gas has to ascend a height of about 40 feet through a furnace filled with considerable sized masses of solid fuel, ironstone, and limestone; and therefore becomes broken up into innumerable separate columns, each of which is again turned in different directions as soon as it meets with another solid obstruction.

Notwithstanding the temporary kind of construction that was adopted for trial in the first furnace, the gas openings made with only 2 inch cast iron plates lasted more than a year, and stood some of the severest treatment that a furnace top can be exposed to, in consequence of a sort of fuel being tried at one time which proved a total failure, and with which the furnace was unable to drive at all; and consequently for two days the whole throat was at a red heat. It was expected that when the furnace did drive below where the openings had been they would be found to have given way. They had not however completely given way in any instance, and though the plates were very much bent they remained at work a great part of a year afterwards. Their standing so well is to be attributed to their position, in the outside of the furnace instead of in the centre; and also to the effect caused by closing the valve on the top of the descending gas main, so that no gas or flame could then pass outwards through the openings, as there was no longer any current to draw the heat through the openings. Had a bell been at work in the centre of the furnace top in this instance, the only way to save it would have been to disconnect it and lift it out entirely; but this could not have been done till the materials in the furnace throat had lowered themselves below the mouth of the bell.

As the gas openings are now cast, as shown in Figs. 5, 6, and 7, it is anticipated they will stand for many years. The repairs also

seem to be quite unimportant, for when required it will only be necessary to change the old set of openings or castings for a new set, and the iron in the set taken out will be nearly equal in weight to that put in.

The advantages of this plan of taking off the gas may be summed up as follows.

The whole height of the furnace throat is left free for charging, which is equivalent to giving additional height to the furnace in comparison with other modes of taking off the gas.

The top of the gas openings being 4 feet below the top of the furnace, as long as the materials are kept charged up to within 3 ft. 6 ins. of the furnace top no damage can be done by flame to the gas apparatus, except by carelessly allowing the chimney draught to be so strong as to take off more than all the gas and consequently draw in some air from the furnace top.

There is no wear and tear from the shocks of the successive barrow loads of material charged, which do so much damage to a cylinder carried upon brick arches or a bell suspended in the furnace throat.

The whole of the gas apparatus is of simpler construction ; and being all placed below the charging platform, it is much cooler and more free for the men to get at. From the large area of the gas openings and neck flue, which allows the dust to be for the most part deposited in the neck flue, the gas apparatus is less liable to become foul ; and this neck flue can be cleaned with the greatest ease whenever required.

From the great strength of the castings forming the gas openings and their advantageous situation, next to no repairs are required, and there are consequently fewer stoppages, and an increased make of iron is the result.

There is also the convenience of being able at any time to burn any portion or even the whole of the gas at the furnace mouth without doing any damage to the gas apparatus.

The experience of the working of this plan of taking off the waste gas at the writer's furnaces is very satisfactory as to yield and greater regularity in make of iron, in consequence of there being

fewer stoppages; whence also there is a great saving of wages. By this plan the desideratum previously mentioned may be very nearly if not quite attained; namely an open-topped furnace where under no circumstances can there be back pressure or the trouble of lifting a charging cone. The ring of openings of 15 inches height, at a depth of not more than 4 feet from the furnace top to the top of the openings, are found able to take off just as much gas as is desired, by opening or closing the gas valve and so only permitting enough gas to escape at the top of the materials to warm and dry them without firing the fuel in the furnace top to any material extent.

In many previous instances the gas has indeed been taken off through the sides of a furnace and into flues in the brickwork of the furnace; but then it has been taken off at so great a depth that its withdrawal from the furnace at so early a period must be injurious; and the openings have been made 3 or 4 feet deep, thereby greatly weakening the structure of the furnace. It is evident that by taking off the gas lower down in a furnace it is taken off under a pressure sufficient to force its way through the materials above that depth, and by this means the gas may be drawn off without so powerful a chimney: but by so doing the working height of the furnace is in effect greatly reduced; and experience shows that in the Staffordshire furnaces at least there is great value in every foot of height that can be worked, while probably a trial would show something valuable in an additional 6 feet of height or more.

Mr. N. Neal Solly said that he fully concurred with the views advanced in the paper as to the advantages of open-topped blast furnaces over those working with a closed top; and having had several years' experience at the Willenhall Furnaces in taking off the waste gas from open-topped furnaces, by means of a bell suspended in the centre of the furnace throat, he was satisfied that the plan described in the present paper was a great improvement, and decidedly superior to the other modes of taking off the gas, as

the suspended bell was liable to frequent accidents. He enquired whether the supply of gas obtained by this means was always found as large and as regular as when taken off by the bell previously used, and whether it had always done the work as satisfactorily in the boilers and hot-blast stoves.

Mr. ADDENBROOKE replied that this plan was found even more effective than the bell suspended in the furnace throat; indeed the ring of openings round the neck of the furnace were capable of taking off the whole quantity of gas that the furnace yielded. By the aid of the powerful chimney draught he had seen the gas so completely drawn off that a man had been able to walk across the top of the materials in the furnace throat, whilst the furnace was working at the rate of 220 tons per week: but in this case there must have been air drawn in through the top of the materials by the draught being unnecessarily strong, which would cause combustion to take place immediately below the surface, where it was very undesirable; and accordingly orders were given to the men that, whenever the flame disappeared entirely at the furnace mouth, the gas valve was to be partially closed until a slight flame appeared again, so as to make sure that no air was being drawn down through the furnace top.

Mr. P. A. MILLWARD, engineer at the Rough Hay Iron Works, Darlaston, said that the gas taken off from the furnaces by the system described in the paper had been found to do its work in the boilers and hot-blast stoves quite as well as when taken off by the bell previously used; and the present plan not only gave the means of drawing off much more gas than was required for heating purposes, but also admitted of taking off the whole of the waste gas from the furnace, though that was more than it was desirable to accomplish.

Mr. J. E. SWINDELL enquired whether the heating of the boilers and hot-blast stoves was not interfered with whenever the gas valve was closed on the occasion of the flame disappearing at the furnace mouth.

Mr. ADDENBROOKE explained that the gas valve was never shut entirely; but whenever the flame disappeared at the furnace top

the valve was partially closed to a sufficient extent to cause a portion of the gas to pass out at the furnace mouth and restore the flame. Even when the gas valve was partially closed however there was an abundant supply of gas for heating purposes; for the furnace produced always more gas than would be required even with the oldest and least economical forms of boilers. The boilers used at the Rough Hay Iron Works were plain cylindrical boilers without any flues, and they supplied steam to the blast engine, and to the engine employed in the fitting shops and for working the wood-sawing machinery and raising the materials for filling the blast furnaces; and the whole of the heating was done by the waste gas, without the use of any other firing. An important advantage in the employment of the waste gas for this purpose had been that it had effected a very considerable saving in repairs both of boilers and hot-blast stoves; the boilers and stoves frequently worked for several weeks together without the firedoors being once opened, so that they were not subjected to the constant exposure to expansion and contraction by alternate heat and cold, and consequently the boiler plates and hot-blast pipes lasted much longer before requiring repairs than when heated by burning coal under them; there had indeed been scarcely any repairs required since the waste gas had been employed for heating.

Mr. J. E. Swindell thought the plan described in the paper was certainly a step in the right direction for taking off the waste gas from open-topped furnaces. In the case of close-topped furnaces, where the whole of the waste gas was taken off, he understood the supply of gas obtained was always found greater than was required for all the purposes to which it was applied; and therefore there seemed no reason to doubt that in the open-topped plan now described a sufficient quantity of gas might always be obtained from the furnace, while still leaving some to burn out at the open top of the furnace. He enquired whether the fuel employed in the furnaces described was all coke.

Mr. Addenbrooke replied that since the present plan of taking off the gas had been adopted the fuel employed in the furnaces had not been entirely coke, but a good deal of coal had been used also.

This had nothing to do however with the mode of taking off the gas, which was equally effective whether coal or coke was employed. In one respect this plan of taking off the gas was certainly invaluable in furnaces where coal was used, as compared with a bell suspended in the mouth of the furnace; for the flame burning out at the mouth of a furnace working with coal was so much hotter than with coke that the bell and the horizontal branch pipe leading from it became very highly heated, and were greatly injured by the flame; but in drawing off the gas by the neck openings below the surface of the materials, no part of the gas apparatus was exposed to the flame in the furnace mouth, and the whole of the flues and pipes were kept so cool that within a few feet of the neck flue the hand could be held upon the $\frac{1}{4}$ inch plates of which the gas main was composed. Moreover in the case of a bell suspended in the furnace mouth the area of the bell was no larger than that of the gas main, and therefore the full force of the chimney draught acted at the bell, causing a large quantity of dust to be drawn off with the gas; but in the present plan the area of the gas openings round the neck of the furnace was greater than that of the gas main, so that the gas came off quietly through the openings and carried over less dust with it; and the dust was then deposited in the neck flue instead of all passing down the gas main.

Mr. J. E. Swindell observed that mention had been made in the paper of a close-topped furnace at Dowlais, from which the gas was carried to a distance of a quarter of a mile before being consumed; and he enquired whether it could be conveyed to as great a distance if required in the mode now described of taking off from open-topped furnaces.

Mr. Addenbrooke replied that in the open-topped furnaces the gas could be taken to any distance, according to the power of the chimney draught, and with the advantage that the working of the furnace would not be affected by any back pressure, whatever might be the distance to which the gas was conveyed. With a more powerful chimney however the gas openings would have to be placed rather lower down in the furnace, so as to avoid drawing in air with the gas. In the case of the close-topped furnace at Dowlais that

had been named, a portion of the gas taken off was employed near the furnace for burning bricks and calcining ironstone; and the rest of the gas was then conveyed to a distance of about a quarter of a mile to heat the boilers of the forge and rolling mill; but the back pressure produced in the furnace top by forcing the gas along such a length of pipe amounted to $\frac{3}{16}$ inch of water, and he understood it was intended to employ a fan for drawing off the gas, so as to diminish this back pressure on the furnace.

Mr. W. Haden enquired whether there would not be some difficulty in replacing the castings forming the gas openings round the neck of the furnace, whenever they required renewal; and whether it would not be advisable to make some provision for replacing them readily in the event of any mishap.

Mr. Addenbrooke replied that with the present strong construction of the castings forming the gas openings, of which a full size model was exhibited, it was not expected that there would be any considerable wear, and there was reason to expect they would last quite as long at least as the lining of the furnace; and as they merely took the place of a few courses of lining at the top of the furnace, they could readily be replaced if requisite at the time of renewing the lining. The durability of the castings would of course depend upon the care with which the furnace was worked, and if there were a flame through the gas openings it would necessarily cause destruction of the iron; but it must be borne in mind that when the working was properly managed, so that a flame was always kept burning out at the furnace top and the loading of the materials kept up to the proper height above the gas openings, the gas was drawn off through the openings without any flame, because no air was then drawn down from the top to produce flame below the surface of the materials; and consequently the castings were not exposed to injury from the passage of the gas through the openings. Even the first gas openings, constructed of only 2 inch cast iron plates, as a temporary expedient by way of making trial of the new plan, had continued satisfactorily in work for upwards of a year, notwithstanding the very severe test to which they were subjected within three months of being put in,

when the whole throat of the furnace had been at a red heat for two days; and the present castings were so much more massive that they were expected to prove much more durable. On the occasion of putting in the new castings in the second furnace to which the plan had been applied, which had been done about nine months ago, advantage had been taken of an opportunity when work was slack; and the blast being turned off, the furnace stood six days with the charge in it while the top was taken down sufficiently far to put in the new set of openings, after which the working was continued again without any inconvenience resulting from the stoppage. At present there had been only nine months' actual experience of the durability of the castings; they did not show any injury, and whenever they might require renewal, the cost of replacing them would not be serious, as the iron originally put in would be nearly all recovered in the old castings taken out.

The Chairman remarked that as the ring of gas openings round the neck of the furnace was composed of separate segmental castings, he presumed it would be practicable at any time to replace a single defective casting without much difficulty; and he enquired what was the weight of each of the castings, and whether they were placed contiguous to one another all round the circle, or whether there was anything interposed between the successive segments.

Mr. Addenbrooke replied that the castings weighed nearly 1 ton each, and were placed close together round the furnace throat without anything between them; and for taking out any one of the castings it would only be necessary to take down the furnace top immediately above that particular casting, so as to allow of lifting it out by a crane and putting in another casting in its place.

Mr. C. P. Sandberg remarked that the utilisation of the waste gas from blast furnaces had been clearly proved to be beneficial, even where fuel was cheap; but the difficulties by which it was attended, namely irregularity in the working of the furnace, increased consumption of fuel per ton of iron produced, and liability to explosions, had to be carefully guarded against, otherwise the result would be a loss instead of a saving.

On the Continent and in Sweden the waste gas had been utilised for twenty to thirty years past. In Sweden Professor N. G. Sefstrom, of the School of Mines at Fahlun, had been the first to employ the gas for the calcining kilns and hot-blast stoves. The gas was taken off through an opening in the wall of the furnace about 5 feet below the top, and the furnace top was left open. The hot-blast stove was placed at the level of the furnace top; and the calcining kiln was also placed in a high position, in order that the gas might not have to be drawn down to a much lower level, which was to be avoided on account of the small pressure of the gas. In some places a vertical cylinder of nearly the same diameter as the furnace mouth was inserted in the top of the furnace, for taking off the gas from the top, thus obtaining a higher pressure; while the surplus gas was allowed to escape through the annular space between the cylinder and the furnace wall. This plan had been applied to charcoal furnaces with but little difficulty, so long as the gas was not required to be drawn down from the furnace top to a lower level; but considerable difficulties had arisen when the fireplace where the gas had to be burned was situated down at the level of the tuyeres, in which case the necessary power for drawing the gas down had not been obtained even with the assistance of an ordinary large chimney; and the result had been a greater consumption of fuel in the furnace instead of a saving. In order to ensure the gas being drawn down, it had been found advantageous to have a pressure of gas in the tube of not less than $\frac{1}{2}$ inch of water at the furnace top and 1-10th inch near the fireplace at the level of the tuyeres.

In conveying the gas through tubes from the furnace top to the fireplaces it was found better to have a positive pressure or plenum inside the tubes; so that the small openings for leakage round the valves, which could scarcely be avoided, might allow the gas to escape, instead of drawing air into the tubes. In the fireplace also the combustion was better effected when the gas was delivered there by pressure than when drawn down by means of a draught. It had also been found necessary to avoid the horizontal gas tube at the top of the furnace, because it was liable to become filled up with dust deposited there from the gas taken off; and it was desirable to

conduct the outer end of the gas tube into a water cistern, which acted both as a receptacle for dust and also as a safety valve.

In coke furnaces the means of obtaining the requisite pressure in the upper part of the furnace for forcing the gas down from the furnace top had generally been by working the furnace with a closed top; but in charcoal furnaces the charge itself acted as a sufficient cover to close the furnace top, the ore being crushed to a fine state; and in these furnaces therefore it was sufficient to lower the opening for the escape of the gas, while the furnace top was left open. The close-topped furnaces were worked in many localities in England and on the Continent, while the open-topped furnaces were employed in some parts of France, Germany, and Sweden; and in the Swedish furnaces charcoal was used exclusively. In the case of six open-topped charcoal furnaces in Sweden of which he had had the management from 1856 to 1860, the hot-blast stoves were removed from the top of the furnaces down to the level of the tuyeres, and the necessary pressure of the gas was obtained by lowering the gas opening down to 14 feet below the top, the height of the furnaces being 42 feet. No chimney was used in connection with the stoves, and no loss of fuel or other objection was caused by taking off the gas so low down in the furnace.

In the plan described in the paper for taking off the waste gas, the use of a chimney draught for drawing down the gas from the furnace top had been carried out to a much greater extent than he had ever seen successfully accomplished before, the gas openings being only 4 feet below the furnace top, which was left entirely open, and the gas being drawn down to the level of the tuyeres entirely by the force of the chimney draught. Such an arrangement appeared a retrograde movement in the principle of taking off the waste gas; but having had the pleasure of seeing the working of this plan at the Rough Hay Furnaces, he had found that it proved completely successful in practice. The supply of gas at the boilers appeared to be plentiful, and the combustion was well regulated; and the whole arrangement was well worthy the attention of every one connected with the working of blast furnaces. He thought however that with the gas openings situated at only 4 feet depth

below the open furnace top, and with such a large chimney for drawing off the gas, there would be need of special care to keep the furnaces at all times well filled and regular in the level of the charge; otherwise air would be drawn down from the top, and entering with the gas into the pipes would cause explosion. The reason assigned for placing the gas openings so near the top of the furnace was that the consumption of fuel had been found to be increased when the gas was taken off at a lower level; but in this respect the experience of the furnaces referred to in the paper differed from that of the Swedish charcoal furnaces, as well as the Continental coke furnaces, where the gas was taken off at a much greater depth below the top without increasing the consumption of fuel.

Mr. Addenbrooke observed that, though the use of a chimney for drawing off the gas from the blast furnace appeared to be little known in connection with the Swedish furnaces, it was by no means new in this country, having been employed previously for furnaces in Staffordshire, as well as in the Yorkshire and Welsh districts. The level at which the gas was drawn off from the furnace had been found in his own experience to be an all-important point; and he did not understand how this could have been found a matter of indifference in the Swedish furnaces.

As regarded the liability to explosion in taking off the gas by the mode described in the paper, he had not found there was any liability to explosion unless through gross carelessness and mismanagement. In Sweden he understood there had been several explosions, and nine or ten hot-blast stoves had been split by explosions; and he thought this was to be accounted for by the plan of taking off the gas, having a plenum of pressure to force the gas down from the furnace top, instead of a chimney draught to draw it down; so that, whenever the stoves were standing idle, there was a liability of some gas being still forced into them through the leakage of the valves; and as there was no draught to carry it off, this would hang in the top of the stoves and form an explosive mixture with the air, and then an explosion would ensue when a light was applied to it. But with the chimney draught as

employed at his own works, the regulations were that the draught was always to be put on the stoves before the gas was admitted, so that there was no opportunity for any explosive mixture to be formed; and he had accordingly had scarcely any accidents by explosion in the use of the waste gas for the boilers and hot-blast stoves.

Mr. John Jones enquired whether in taking off the waste gas by the plan described in the paper the production of pig iron by the furnaces had been greater or less than before the gas was taken off.

Mr. Addenbrooke replied that the production of pig iron had certainly been found to be increased since the waste gas had been taken off, the make of each furnace having now got up to more than 200 tons per week, instead of the former make of only 150 or 160 tons per week. He did not consider however that the whole of this increase of make was to be attributed to taking off the waste gas, as he thought it was partly due to the use of the new gunmetal tuyeres, which had recently been adopted for blowing the furnaces, and which formed the subject of another paper at this meeting. Another advantage which had been experienced was that the quality of the iron made was very much more regular than before the gas was taken off from the furnaces.

The Chairman moved a vote of thanks to Mr. Addenbrooke for his paper, which was passed.

The following paper, communicated through Mr. Addenbrooke, was then read:—

DESCRIPTION OF A GUNMETAL TUYERE FOR BLAST FURNACES.

By Mr. N. NEAL SOLLY, of Willenhall.

For the Tuyeres of Blast Furnaces there are two distinct kinds of iron water tuyeres generally in use.

The first of these is the Cast Iron or Scotch tuyere, which is made of a coil of wrought iron tube imbedded in the sides of a hollow cone of cast iron, as shown in Figs. 1 and 2, Plate 71; each end of the coil projects from the back end of the cone, and through this coil the water for cooling the tuyere circulates, as shown by the arrows. This construction of tuyere is generally in use in Scotland, North Staffordshire, Cumberland, and parts of Wales, &c. A tuyere formed of a coil of wrought iron tube not imbedded in cast iron is also used in some places.

The second tuyere is the Wrought Iron or Staffordshire tuyere, which is shown in Figs. 3 and 4. It is forged out of boiler plate, and is made in the form of a truncated cone, the sides being hollow to allow of the circulation of water through them. The water enters from a pipe through a hole on the lower side of the outer end or back of the tuyere, and is discharged in a similar way from the upper side, as shown by the arrows.

In each description of tuyere the blast enters the furnace through a wrought iron nozzle pipe placed in the axis or centre of the conical tuyere. Although both these kinds of iron tuyeres are a great improvement upon the tuyeres that were used before the introduction of the hot blast, the chief objection to them consists in the fact, that after they have been at work a comparatively short time, which is very variable, being sometimes only one or two days, the iron of the furnace and iron mixed with cinder accumulate

round the nose of the tuyere and begin to adhere to it, or in technical language the tuyere "irons," as shown at A A in Fig. 4. As this accumulation goes on increasing, the entrance of the blast into the furnace is much impeded by the diminution of the tuyere aperture. In the case of the wrought iron tuyere, the tuyere has then to be taken out and changed, an operation attended with much labour and occupying about three quarters of an hour, during which time the blast has to be taken off the furnace; whilst in the cast iron tuyere, when it has "ironed" badly, the accumulation of iron round the cast iron nose is so great as to render it necessary to shut off the water and burn off the entire end of the tuyere, before the tuyere can be taken out; this burning off requires several hours to accomplish, during which time the good working of the furnace is interfered with, while the value of the tuyere and nozzle pipe is of course sacrificed.

The new tuyere, forming the subject of the present paper, is shown in Figs. 5 and 6, Plate 72, and is made of Gunmetal, that is copper alloyed with small proportions of tin and spelter. As copper whether pure or alloyed has no affinity whatever for iron, no iron or other material from the furnace becomes attached to the tuyere nose, however long a time it may have been in the furnace: in fact the gunmetal tuyere never "irons," and therefore rarely requires to be taken out or changed, from which circumstance many advantages arise.

After various experiments had been made by the writer as to the form and thickness of tuyeres made entirely of gunmetal in different proportions, and also with tuyeres having the outer end made of iron and only the nose end of gunmetal, the form of the ordinary wrought iron tuyere was adopted, as shown in Figs. 5 and 6. Fig. 6 represents the longitudinal section of a gunmetal tuyere, 20 inches long, 11 inches diameter at the outer end, and 8 inches at the nose end, with $3\frac{1}{2}$ inches diameter of opening: the wrought iron nozzle B of the blast pipe is also shown in its place in the axis of the tuyere. Fig. 5 is an elevation of the back end of the tuyere, showing the position of the two water holes.

In this tuyere, instead of the supply water pipe C being simply inserted into the back end, as is the case in the wrought iron tuyeres, without entering the water space, the pipe is carried forwards inside the tuyere to within 4 or 5 inches of the nose end, so that the fresh cold water is delivered close to the nose end, which has been found to ensure a more effective action of the water in keeping the tuyere nose cool.

The first gunmetal tuyere of nearly this form was put to work at the writer's furnaces at Willenhall on 18th January last, and has been at work ever since until last week, when it was taken out for the purpose of being sent to the present meeting, and is now exhibited. There is also exhibited a gunmetal tuyere of the pattern since more generally adopted, which has been at work for three months in the same furnaces; and also an ordinary wrought iron tuyere taken out after only a few days' work, showing how the nose "irons." With respect to the first gunmetal tuyere now exhibited, it has to be observed that when first cast it was an imperfect casting, and was patched by running some gunmetal over part of the nose end a second time; notwithstanding this disadvantage however it has worked for nine months with scarcely any signs of failing. Another fact deserving of special notice in connection with this first gunmetal tuyere is that it was originally cast 1 inch thick at the nose, but after being put to work it got gradually reduced to its present thickness of about $\frac{1}{2}$ inch; this took place by small holes forming in the metal at the nose end and the surface getting gradually melted down until it arrived at the proper thickness, since which time there has been no further change of any consequence. This thickness of $\frac{1}{2}$ inch at the nose is therefore the one which has now been permanently adopted, and the sides of the tuyere are made $\frac{3}{8}$ inch thick. A specimen of a gunmetal tuyere slotted down the centre is also shown.

As gunmetal melts at a lower temperature than iron, a full and constant supply of water from a head or cistern raised a good height above the tuyeres must be kept continually flowing through these gunmetal tuyeres; and for the same reason it is of importance

when the tuyere is changed that the water should be kept on till the tuyere is quite ready to come out. When the tuyere is to be taken out, a sharp bar must not be employed to loosen it, such as is used in the case of the ordinary wrought iron tuyeres; but a round-ended bar with the head projecting on one side so as to fit the end of the gunmetal tuyere, as shown in Fig. 8, Plate 73, answers the purpose completely. If these points are carefully attended to, the nose of the tuyere is found not to be liable to be injured or cut off.

The water cistern for the supply of the tuyeres should be placed at a height equal to that of the furnace, wherever practicable, in order to ensure a rapid circulation of water. The water pipes to the tuyere are 1 inch bore, and a little hemp and white lead is put round the pipes where they are inserted into the tuyere, to make a water-tight joint; and a few inches behind the joint a small collar D is welded on the pipe, Fig. 6, to serve as a butt for the furnaceman's hammer to strike against for driving up the water pipe tighter.

If a deposit of sediment is found to be formed in the gunmetal tuyere from the water that is supplied to the tuyere, it should be allowed to become quite cold when taken out, and then on its being knocked with a hammer the scale is all easily detached from the metal and falls out. If however the water is allowed to flow through the tuyere in a good stream, so that the water is always cool, but little sediment is deposited, as it is only boiling water that causes much scale. In the ordinary wrought iron tuyere on the other hand it is usual to keep the water as hot as possible, because it is found that the tuyere then "irons" less, although there is more deposit of sediment in consequence. But as the gunmetal tuyere never "irons," the colder the water is kept, the better; and in practice the water running away from the gunmetal tuyere is only slightly warmed.

On putting a new hearth and boshes into a furnace where the gunmetal tuyeres are used, the tuyere openings may be built smaller than is usual, because a large hole is not required to be made around the tuyere for getting it out, as is requisite with the

ordinary wrought iron tuyeres. This affords additional substance and strength to the furnace hearth.

Amongst the advantages of the gunmetal tuyeres are the saving of labour and the comfort to the furnacemen, especially in hot casting houses, where the labour of changing a tuyere that has "ironed" is very severe and exhausting, on account of the quantity of hard-set material that impedes its being taken out. On account of the saving of time in tuyering, the length of time that the blast is off the furnace at casting time is shortened half an hour, both night and morning, as compared with the ordinary wrought iron tuyeres; and when it is borne in mind that the operation of casting is repeated more than 600 times in a year, it is obvious that this saving must amount to a considerable gain in the make of iron during the year.

The gunmetal tuyere is readily changed in a quarter of an hour, instead of requiring three quarters of an hour as in the case of the ordinary wrought iron tuyeres; and it only requires to be changed when the tuyere sides work hot, which, if the supply of water is duly kept up, can only occur from accumulation of sediment inside the tuyere. At the writer's furnaces at Willenhall the same gunmetal tuyere has at times continued at work for three entire months without once changing; nor have any of the gunmetal tuyeres been injured or met with any accident since they were first put to work there nearly ten months ago.

In consequence of the size of aperture of the gunmetal tuyere remaining unchanged during working, instead of becoming gradually diminished by the accumulation of iron on the nose, as in the wrought iron tuyere, the blast enters the furnace freely, and the size of the nozzle pipes B has accordingly been reduced with the gunmetal tuyeres: this has also been found necessary at the Parkfield Furnaces, near Wolverhampton, and other furnaces where the gunmetal tuyeres are in use. This is advantageous as producing regularity in the supply of blast entering the furnace. There is also an important saving in fuel and wages with the gunmetal tuyeres.

The above advantages are found to be obtained from the gunmetal tuyeres, when they are carefully used; at the same time, like all improvements, they require some little care and attention at first to ensure their success, especially on the part of furnace managers. It is necessary to see that the water is kept on by night as constantly as by day; and that the tuyeres receive fair play in every respect from the workmen. An alarm whistle may be attached to the supply water pipe of the tuyere, to be acted on by the blast and give immediate warning in case of the water supply ever failing. There is generally a prejudice in the minds of furnacemen against any novelty, and the blacksmiths especially connected with blast furnaces may naturally be expected not to be favourably disposed towards what they regard as depriving them of a great part of their employment. When this prejudice however is once overcome, the furnacemen themselves have been found to be foremost in recognising the advantages and saving of the gunmetal tuyeres.

In Fig. 7, Plate 73, is shown a longitudinal section of an improved gunmetal tuyere having the inside made parallel or cylindrical for a distance of 4 inches from the nose end, so that the tuyere itself forms the blast nozzle of $2\frac{3}{4}$ inches diameter, while the end of the blast pipe B of 4 inches diameter is inserted into the taper part of the tuyere as far as it will go, and rammed up tightly with fireclay stopping. This form of tuyere is considered by the writer to be a great improvement on the form originally adopted for the gunmetal tuyeres, because the effect of the cylindrical nozzle is that the blast is projected with more force straight into the furnace, and to a greater distance than from a nozzle pipe which tapers to the end; for a tapering nozzle favours the divergence of the blast, and too much taper is especially injurious, by causing the destruction of the brickwork round the tuyere inside the furnace. The inside of the parallel nozzle is cast large enough to be bored out so as to ensure its being perfectly cylindrical. In case of requiring to blow with a larger nozzle, say 4 inches diameter instead of $2\frac{3}{4}$ inches, the tuyere itself must be made exactly to that extent of $1\frac{1}{4}$ inch larger in diameter at both ends; or if a smaller nozzle is wanted, of only 2 or $2\frac{1}{4}$ inches diameter, the tuyere must be diminished in the same

way at both ends: this will ensure the proper taper of the back end of the tuyere, and the right position of the blast pipe, and no other alteration will be required in the shape or size of the tuyere.

Mr. Solly exhibited specimens of the gunmetal tuyeres, one of which had been nine months at work, and still did not show any signs of injury; and he explained that they had only been removed from the blast furnace for the purpose of being exhibited to the meeting. He showed also one of the ordinary wrought iron tuyeres, which had had to be taken out after only three days' work, in consequence of having ironed very badly at the nose. At his own works he had never had a single gunmetal tuyere injured since they were first put to work about ten months ago; and he believed that had also been the experience at all other furnaces where the gunmetal tuyeres were in use, provided they were worked entirely with "mine." But at one furnace worked with cinder, a scaffolding had taken place in the furnace, so that the charge had stuck fast and accumulated at a certain height above the tuyeres; and when a sudden drop of the material took place, it had cut into the tuyeres, and it had been necessary to have the tuyeres taken out and recast. The accident was owing to the boshes of the furnace not being in good order and not being sufficiently inclined.

The Chairman enquired what was the cost of the gunmetal tuyeres, as compared with the ordinary wrought iron tuyeres.

Mr. Solly replied that the gunmetal tuyeres cost between £5 and £7 each, according to the size of the tuyeres and the quality and cost of the gunmetal employed, the expense of casting the tuyeres being but little more than in the case of ordinary brass castings. An ordinary wrought iron tuyere weighed about 140 lbs., and the cost of the iron was about 10*s.* per cwt., while the labour expended upon the manufacture amounted to $2\frac{1}{2}d.$ per lb., so that the entire cost was about £2, or about one-third the cost of the gunmetal tuyeres.

The wrought iron tuyere however was speedily destroyed by the ironing in the blast furnace; while the gunmetal tuyeres were not only very durable, but whenever they had to be replaced, could be recast with scarcely any loss of metal. It must further be borne in mind that the cost of the tuyeres themselves was of very little consequence in comparison with the waste of material in the furnace and the consequent loss of make of iron from the furnace having to be kept standing with the blast off, whenever the ordinary wrought iron tuyeres required attention; and in this respect the use of the gunmetal tuyeres effected a saving which far outweighed their extra cost.

The CHAIRMAN enquired what was the average length of time that an ordinary wrought iron tuyere was found to last.

Mr. SOLLY replied that it was impossible to name any particular time for the duration of a wrought iron tuyere, as it was altogether a matter of chance how long it would work. The wrought iron tuyere now exhibited had worked only three days after being first put in new; and the longest time that he had known one last was not more than three or four months, during which the tuyere had required frequently taking out for repairs, and it had become at length so much shortened by continually cutting off the extremity of the nose that it could no longer be made use of. The specimens that were exhibited of the gunmetal tuyeres on the other hand, one of which had been in constant work for nine months, showed at present no signs whatever of even becoming worn.

Mr. ADDENBROOKE said he had made a trial of one of the gunmetal tuyeres, and found that it lasted without giving the slightest trouble during the time that a large number of wrought iron tuyeres blowing the same furnace had to be successively replaced; and he had been so completely satisfied with the results of the trial that he had adopted the gunmetal tuyeres for both the furnaces at his works, and had entirely abandoned the wrought iron tuyeres. With regard to the extra cost of the gunmetal tuyeres in the first instance, he was convinced that it was far more than compensated for by the important practical advantages attending their use.

The Chairman enquired how many of the gunmetal tuyeres were already at work.

Mr. Solly replied that he had had the gunmetal tuyeres in regular work at his own furnaces for nine months past, but they had only been introduced elsewhere for about six months; and there were now about a dozen furnaces at other works blown entirely by the gunmetal tuyeres.

The Chairman moved a vote of thanks to Mr. Solly for his paper, which was passed.

The Meeting then terminated.
